United States District Court
Northern District of Oklahoma

Expert Report of Michael J. McGuire, PhD, PE, BCEE

January 26, 2009

Prepared for

State of Oklahoma, et al. v. Tyson Foods, Inc., et al.
Case No. 4:05-cv-00329-GKF-PJC

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EXHIBIT
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ABBREVIATIONS/ACRONYMS

AOC	assimilable organic carbon
BBPWA	Broken Bow PWA
BDOC	biodegradable organic carbon
CDM	Camp Dresser & McKee
CLSA	closed-loop stripping analysis
CWS	Community Water System
DBP	disinfection byproduct
DBPMX	distribution system sampling point with maximum residence time
DBPR	Disinfection Byproducts Rule
DOC	dissolved organic carbon
EWG	Environmental Working Group
HAA	haloacetic acid
HAA5	sum of five HAAs
IDSE	Initial Distribution System Evaluation
IRW	Illinois River Watershed
LRAA	Locational Running Annual Average
MIB	2-methylisoborneol
N	Nitrogen
n	number of data points
O&M	Operation and Maintenance
OWRB	Oklahoma Water Resources Board
OTC	odor threshold concentration
Ppb	part per billion
PWA	Public Works Authority
PWS	Public Water System
RAA	Running Annual Average
SDSTHM	simulated distribution system THM
SMCL	secondary maximum contaminant level
SUVA	Specific Ultraviolet Absorbance
T&O	taste and odor
THM	trihalomethane
THMFP	THM formation potential
TTHM	Total trihalomethane
TON	threshold odor number
TTC	taste threshold concentration
UCMR	Unregulated Contaminant Monitoring Rule
USGS	U.S. Geological Survey
WHO	World Health Organization
WTP	water treatment plant

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INTRODUCTION

In this report, I will present my expert opinions on the drinking water quality characteristics of water served to people in the Illinois River Watershed (IRW), a discussion of the expert opinions presented by several of the plaintiffs' experts, and a summary of my education, experience and qualifications.

My expert opinions are based upon my evaluation of the scientific literature as well as my education, experience and qualifications in the field of disinfection byproducts, taste and odor, cyanobacteria production, groundwater quality and regulatory compliance in the drinking water field.

I have been retained as an expert testifying witness for the defendants in the case shown on the title sheet of this report. My billing rate is $400 per hour, plus expenses, and plus the time spent by colleagues assisting me under my direction at their established billing rates. A copy of my resume is included in Appendix A, which lists my published articles and papers, depositions and court testimony.

SUMMARY OF EXPERT OPINIONS

1. It is my opinion, based on a reasonable degree of scientific certainty, that application of poultry litter to fields in the IRW has no discernable impact on the levels of total organic carbon in IRW waters. The production of trihalomethanes and haloacetic acids in water served by utilities providing drinking water from Lake Tenkiller and the Illinois River cannot be linked to the application of poultry litter in the IRW. The only DBP MCL compliance problems in the IRW are associated with three utilities (out of 18) and are caused by ineffective design or operation of their treatment facilities and not poultry litter. It is also my opinion that there is no imminent and substantial endangerment to human health associated with disinfection by-products in drinking water served by IRW utilities.

2. Based upon a reasonable degree of scientific certainty, it is my opinion that the evidence and opinions presented by plaintiffs' experts do not establish that there are significant taste and odor problems in the Illinois River Watershed, including Lake Tenkiller. Poultry litter cannot be considered the source of problems that have not been proven.

3. It is my opinion, based upon a reasonable degree of scientific certainty, that the plaintiffs' experts have not demonstrated any link between the two low level concentrations of microcystin found in Lake Tenkiller with poultry litter use in the IRW. It is also my

opinion that there is no imminent and substantial endangerment to human health associated with cyanotoxins in drinking water served by IRW utilities.

4. It is my opinion, based upon a reasonable degree of scientific certainty, that no connection has been made by the plaintiffs' experts between nitrate as a result of field application of poultry litter and nitrate concentrations in residential wells in the IRW and that no remediation of residential wells is necessary.

5. It is my opinion, based upon a reasonable degree of scientific certainty, that the water served to customers of utilities using the Illinois River and Lake Tenkiller is safe and does not pose a danger to human health.

EDUCATION, EXPERIENCE AND QUALIFICATIONS

I received my Bachelor of Science degree in civil engineering from the University of Pennsylvania (Philadelphia, Pennsylvania) in 1969. My Master of Science degree in environmental engineering was earned at Drexel University (Philadelphia, Pennsylvania) in 1972 while working full time for the Philadelphia Water Department. I finished my Doctor of Philosophy degree (environmental engineering) also at Drexel University in 1977.

I am currently employed as President of Michael J. McGuire, Inc. which is headquartered in Los Angeles, California. From April 1, 2005 to August 1, 2008, I was a Vice President with the consulting engineering firm Malcolm Pirnie, Inc. (MP) in Santa Monica, California. I was President and CEO of McGuire Environmental Consultants, Inc. (MEC) from 1992 to 2005. Prior to that (1979 to 1992), I held several positions with the Metropolitan Water District of Southern California (Metropolitan), the largest drinking water utility in the United States. Between 1984 and 1990, I was Director of Water Quality where I was responsible for the water quality being delivered to 16 million people in Southern California. Before Metropolitan, I worked for a national consulting engineering firm, Brown and Caldwell; for Drexel University as a research assistant; and for the Philadelphia Water Department as a civil/sanitary engineer.

Taste and Odor

I have been actively engaged in the field of taste and odor problems in drinking water since 1973 when I took my qualifying exams for my Ph.D. in the theory of taste and odor detection, occurrence and treatment. At Metropolitan during 1979 to 1990, I instituted the most comprehensive taste and odor control program of any water utility in the U.S. Elements of the program included:

- Management of the design and implementation of an innovative analytical methodology to determine earthy/musty odorants at part-per-trillion levels—closed-loop stripping analysis, which has been included in *Standard Methods* since the 16th edition in the early 1980s.

- Adaptation of the Flavor Profile Analysis (FPA) method from the food and beverage industry for use in drinking water taste and odor evaluations. The FPA method is also included in *Standard Methods.*

- Design of a comprehensive research program to determine the cause of earthy/musty odor problems in six, very large Southern California reservoirs. Once the causes were determined, an early warning system and effective taste and odor control strategies were implemented in those reservoirs.

- Management of an extensive research project funded by the American Water Works Association (AWWA) Research Foundation, "Optimization of the PEROXONE Process for Disinfection By-Product Formation, Taste and Odor Control, and Disinfection," 1988-90.

Developing the taste and odor early warning system at Metropolitan required the establishment of a cyanobacteria monitoring program in two major reservoirs (Lake Mathews and Lake Skinner). I developed a comprehensive reservoir sampling program in concert with microbiologists on my staff which included the use of Scuba divers to sample benthic blue-green algae growths. Planktonic algae were monitored extensively especially during critical taste and odor events in these reservoirs.

While at Metropolitan, I was directly responsible for fielding and managing the resolution of thousands of consumer complaints related to taste and odor problems as well as other water quality issues.

From 1992 to 2008 while I was employed by MEC and MP, I managed and conducted dozens of taste and odor research investigations and projects for water utility clients to identify and solve specific taste and odor problems. I have designed and conducted four consumer panel studies of the taste and odor characteristics of various constituents in drinking water. The consumer panels have consisted of 57 to 100 people and have investigated the impacts of reverse osmosis treatment, MTBE concentrations, high mineral content, chlorine concentrations and water hardness levels in water supplies.

I have been involved with the AWWA Taste and Odor Committee as a member (1983-85, 2000-2004); Chair (1993-1998); and liaison as Trustee of the Water Quality and Technology Division (2004-present). I have been a member of the Specialist Group on Tastes and Odors in Drinking Water (1983-present) under the International Water Association (and preceding organizations). For that group I was the Keynote Speaker at the Fourth International Symposium on Off-Flavors in the Aquatic Environment, October 2-7, 1994, in Adelaide, Australia. Along with two others, I edited the proceedings of that symposium.

In 1998 and 1999, I was an expert consultant to a study that determined the odor threshold concentration of MTBE in drinking water of 15 parts per billion (ppb) using, for the first time, a consumer panel and a standard method (ASTM Method E679-91). Generally referred to as the Stocking study, the results of this investigation were used by Health Canada to set a Canadian drinking water guideline for MTBE of 15 ppb.

I was designated as an expert witness, accepted by the court and testified at trial in 2002 on the taste and odor characteristics of MTBE in drinking water as part of the case designated *South Tahoe Public Utility District vs. Atlantic Richfield Company et al. No. 999128, Superior Court of California, County of San Francisco.*

Disinfection Byproducts

I have been directly involved in the field of disinfection byproduct occurrence and control ever since trihalomethanes were discovered in drinking water in 1974. I managed and led the evaluation of alternative strategies for compliance with DBP regulations at the Metropolitan Water District of Southern California during the 1980's and early 1990's as Director of Water Quality. These efforts included the direct oversight of bench-scale and pilot-scale studies assessing granular activated carbon, chlorine/chloramine disinfection/DBP control and ozone/PEROXONE oxidation. The construction and operation of a $13 million oxidation demonstration facility at the F.E. Weymouth water treatment plant followed these bench and pilot studies. This work was ultimately published in numerous journals and as reports to the American Water Works Association Research Foundation.

In 1992-1993, 1996-1997, and 1999-2000, I was the lead technical resource for the Reg Neg and FACA negotiation processes which resulted in stakeholder agreements for far-reaching federal water regulations. I participated in all three efforts as a member of the Technology Working Group (TWG) whose job was to provide answers to cost and technical questions posed by the negotiators. I presented all of the findings of the TWG to the negotiators and acted as the "translator" of technical and policy issues. The Stage 2 regulatory negotiation efforts that concluded in 2000 resulted in the proposed Stage 2 DBP regulation that was promulgated on January 4, 2006.

During 1999 and 2000, I played a major role in the development and implementation of a data analysis plan for the Information Collection Rule (ICR) data. I provided leadership in not only analyzing the data but also in devising methodologies for presenting the results to interested stakeholders and the Stage 2 DBP negotiation committee. My interest in ICR data analysis continued when I served as senior editor of a book entitled *Information Collection Rule Data Analysis* which was published in 2002.

Since 1992, I have consulted with dozens of water utilities in the U.S. helping them devise control strategies for trihalomethanes and haloacetic acids in the water delivered to their customers. Clients have included Contra Costa Water District, California; Santa Barbara, California; Tucson, Arizona; Phoenix, Arizona; Valencia, California; Philadelphia, Pennsylvania; New York, New York; Dallas, Texas; and Carlsbad, California. Currently, I have been re-engaged by the Phoenix Water Department to review their strategy for using granular activated carbon to control DBP concentrations in its distribution system.

Regulatory Development Experience

During my tenure at Metropolitan, I was involved in developing several State and federal drinking water regulations. In the early 1980s, I assisted California in the design of the initial volatile organic chemical monitoring program that led to maximum contaminant levels for TCE and PCE in the State. I led negotiations for water utilities with the California Department of Health Services for the development of the California Surface Water Treatment Rule. From 1987 to 1990, I was a member of the USEPA Peer Review Workgroup that developed definitions of best available technology (BAT) for controlling synthetic organic chemicals and volatile organic chemicals in drinking water.

Already covered in this section of the report is my detailed involvement in the negotiation, drafting and promulgation of the Stage 1 and Stage 2 DBP regulations.

In 1998-1999, I was a member of the Committee on Drinking Water Contaminants under the National Research Council. As part of this Committee, I helped evaluate a scientifically sound approach to develop future Contaminant Candidate Lists and to determine the criteria for regulating (or not) contaminants that appear on the lists.

Reservoir Management and Cyanotoxin Experience

While Water Quality Manager and Director of Water Quality at Metropolitan, I was responsible for the water quality in two large reservoirs owned and operated by Metropolitan—Lake Mathews and Lake Skinner (44,200 acre feet). I was also responsible for monitoring water quality at three very large reservoirs operated by the California Department of Water Resources—Castaic Lake (323,700 acre feet), Lake Silverwood (73,000 acre feet) and Lake Perris (125,000 acre feet). These reservoirs were the sources of supply for Metropolitan's five very large treatment plants with a total design capacity of 1,700 mgd. Turbidity spikes, pH excursions, and taste and odor problems were part of my water quality management responsibility. I managed staff collection of in-reservoir water quality data including temperature and dissolved oxygen profiles, as well as enumerations of planktonic and benthic algae (including cyanobacteria).

I designed a comprehensive research program to determine the cause of earthy-musty odor problems in these reservoirs and designed an in-reservoir taste and odor control strategy using judicious applications of copper sulfate. Determinations of nitrogen and phosphorus inputs were part of the reservoir evaluations. I have personally executed water quality inspection dives in all of these reservoirs except for Lake Silverwood. Cyanotoxins were just being recognized as an important reservoir management issue when I was at Metropolitan. We evaluated the potential contamination of the water supply reservoirs by cyanotoxins but no analytical methods were available at that time to monitor concentrations.

Lake Youngs is a critical component of the water supply system for the City of Seattle, Washington. I investigated the turbidity excursions and taste and odor problems that occurred in the reservoir and recommended strategies for reservoir destratification.

I evaluated the source of earthy-musty odors in Lauro Reservoir which serves the Cater Water Treatment Plant for Santa Barbara, California. The sources of the odors were benthic growths of blue-green algae that produced both geosmin and MIB. Similarly, I consulted with the operators of Lake Casitas (254,000 acre feet) in Ventura County, California. Sources of their taste and odor problems were both benthic and planktonic blue-green algae growths. I evaluated the effectiveness of the Lake Casitas hypolimnetic aeration system.

I also evaluated the taste and odor problems on the Poudre River and Horsetooth Reservoir and prepared a taste and odor control research program for the Fort Collins, Colorado water utility.

Groundwater Contamination and Water Quality Concerns

Since January 1980 when I supervised the confirmatory analysis of volatile organic chemicals in a groundwater sample from the San Gabriel Valley, I have been involved in numerous investigations of groundwater contamination by organic and inorganic constituents.

From 1997 to 2008, I provided technical assistance to the Main San Gabriel Basin Watermaster to oversee numerous studies investigating nitrate and perchlorate removal from groundwater. This assistance included the review of current knowledge of nitrate and perchlorate ion treatment methods, preparation of RFPs on behalf of the Watermaster to solicit treatment proposal ideas, review and evaluation of the proposals, project management functions, review of the project findings from the project teams and acted as an interface with regulatory agencies--California Department of Health Services and Region IX USEPA. I also supervised the design and operation of ion exchange pilot studies for nitrate and perchlorate control in the San Gabriel Valley. I recently co-authored a paper on the possible national treatment costs for alternative perchlorate MCLs should an MCL be established by the USEPA. The impact of nitrate co-occurrence with perchlorate was an important part of that assessment.

In May of 1994, a nitrification episode and loss of chloramine residual occurred in the treatment and distribution system of the Long Beach Water Department (LBWD). I prepared a report which characterized the organic and inorganic substances present in the well supplies of LBWD. Based on the data collection phase, operational alternatives were developed so that LBWD could avoid future problems with nitrification and loss of disinfectant residual in the distribution system.

I have provided a variety of consulting services to Mesa Consolidated Water District dealing with the marginal water quality in two of the District's wells that required removal of color. I managed extensive pilot-scale studies of the ozonation of the colored groundwater with related bromate control technologies.

During my extensive consulting activities in Tucson, Arizona (1993-2007), I evaluated the water quality changes in Colorado River Water, which was subjected to groundwater infiltration and subsequent extraction for potable purposes. A unique total organic carbon removal mechanism (up to 50% removal) during soil passage was documented and investigated.

Since September 2000, I have assisted the City of Glendale, California, in its efforts to control concentrations of hexavalent chromium in its groundwater supply. I have conducted and managed numerous bench- and pilot-scale treatment investigations to remove hexavalent chromium from groundwater.

Drinking Water Quality Management and Regulatory Compliance

As mentioned previously, from 1979 to 1992, I worked for the Metropolitan Water District of Southern California—the largest drinking water utility in the U.S. As Water Quality Manager and then Director of Water Quality, I was responsible for the control of water quality and regulatory compliance at five water treatment plants with a design capacity of 1,700 mgd and for a distribution system serving up to 16 million people in Southern California.

As Director of Water Quality for Metropolitan, I managed that utility's development of a Total Coliform Rule Action Plan from 1986 to 1990. I also managed Metropolitan's development of a Surface Water Treatment Rule Action Plan from 1986 to 1990 which included comment on the proposed rule at the State and federal levels, determination of potential compliance/non-compliance by evaluating treatment plant turbidity, tracer and CT data, organizing the capital spending program to make needed treatment plant improvements for monitoring disinfectant residuals and turbidity, reorganizing the Treatment Plant Liaison Unit staff to deal with expanded responsibilities under the Rule, hiring new staff, training staff in the Water Quality Laboratory and five treatment plants and coordinating process and operational changes with Metropolitan's 27 member agencies.

While I was responsible for regulatory compliance at the Metropolitan Water District of Southern California, there were no violations of any kind of State and federal drinking water regulations.

As President of McGuire Environmental Consultants, Inc. and Michael J. McGuire, Inc., I have provided consulting services on regulatory compliance to dozens of water utility clients throughout the U.S.

RELEVANT DRINKING WATER LEGISLATION

Safe Drinking Water Act of 1974 and Amendments

In 1974, the Safe Drinking Water Act (SDWA) was signed into law as a result of a number of factors, including an increase in public environmental awareness, the detection of trace levels of organic compounds in the City of New Orleans' water supply and an epidemiological study linking higher cancer rates with consumption of treated Mississippi River water. For the first time, the SDWA authorized the federal government (the USEPA) to establish national drinking water regulations. National Interim Primary Drinking Water Regulations (NIPDWR) promulgated in 1975 were primarily the adoption of the 1962 U. S. Public Health Service standards. Other regulations were slow to appear. The 1979 trihalomethane (THM) regulation was one of the few new drinking water regulatory initiatives developed by the USEPA under the 1974 SDWA.

In 1986, the Congress, frustrated with the lack of progress by the USEPA in meeting the regulatory agenda, passed amendments to the SDWA which dramatically altered USEPA's ability to select the contaminants to regulate and which specified the implementation schedule. Under the 1986 SDWA Amendments, USEPA was required to set both Maximum Contaminant Level Goals (MCLGs) and Maximum Contaminant Levels (MCLs) for a specific list of 83 contaminants that had been listed in the *Federal Register*. USEPA was given the flexibility of establishing a treatment technique instead of MCLGs/MCLs if a suitable analytical technique did not exist. A number of regulations were promulgated under the 1986 amendments including Phase 2/Phase 5 regulations, the Surface Water Treatment Rule and the Total Coliform Rule.

Congress again amended the SDWA in 1996 to remove the requirement for the USEPA to regulate 25 contaminants every three years plus other modifications and updates. The USEPA was required to create a Contaminant Candidate List (CCL) every five years. The 1996 amendments established a number of regulatory deadlines, including schedules for Stage 1 and Stage 2 Disinfection Byproduct Rules (DBPRs).

A significant new requirement under the 1996 amendments was that each water utility would have to create and distribute a yearly Consumer Confidence Report (CCR) to their customers. The CCRs were designed to provide information to consumers on the regulatory compliance progress of each utility and to communicate levels of contaminants of concern to consumers as well as information on health risks associated with the presence of contaminants in drinking water.

State Primacy Under the SDWA

A cornerstone of the original SDWA and both amendments was the establishment of primacy by State regulatory agencies. Under the SDWA, each state is required to promulgate and implement drinking water regulations that were at least as stringent as the federal rules. The State of Oklahoma's Public Water Supply program under the auspices of the Oklahoma Department of Environmental Quality (ODEQ) currently regulates more than 1,600 public water supply systems. These 1,600 public water supply systems serve about 3.2 million customers.

WATER TREATMENT IN ILLINOIS RIVER AND LAKE TENKILLER WATERSHED

Water Utilities in IRW

Figure 1 shows the locations of the water treatment plant intakes in the Oklahoma section of the IRW. This figure was originally published in the expert report by Cooke and Welch (2008a). Three of the utilities withdraw water from the Illinois River or its tributaries above Lake Tenkiller. The 15 remaining IRW utilities withdraw water from Lake Tenkiller or downstream of Lake Tenkiller. As noted on Figure 1, the utilities withdrawing water from Lake Tenkiller are distributed along the east and west shorelines. Sequoyah County RWD #5 withdraws water from the Illinois River below Lake Tenkiller dam.

There are a number of other utilities that use the IRW as a source of supply, but they are located in the Arkansas portion of the watershed and are not the subject of this report or the plaintiffs' case.

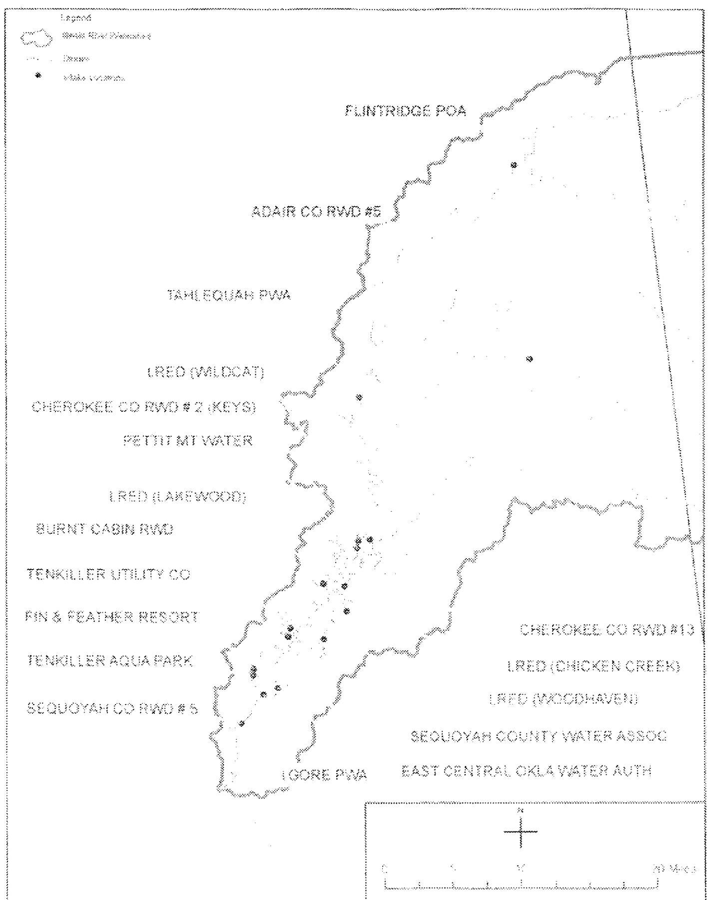

Figure 1. Water Treatment Plant Intakes in the Oklahoma Portion of the Illinois River Watershed (Cooke and Welch 2008a)

Table 1 lists the 18 utilities in the IRW that will be the major focus of this report. Populations served by these utilities range from 90 to 18,431 (ODEQ 2008a). Several of these utilities sell most of their water during the summer tourist season. For regulations adopted under the SDWA, sampling requirements for these utilities vary significantly due to system size.

Table 1. IRW Water Utilities and Populations Served (ODEQ 2008a)

Water System Number	Water Utility Name	Population Served*, [a]
OK1021770	Adair Co RWD 5	950
OK1021763	Burnt Cabin RWD	118
OK1021711	Cherokee CO 2 (Keys)	1,239
OK1021721	Chrokee CO RWD 13	2,120
OK1021713	East Central OK	1,200
OK1021730	Fin Feather Resort	150
OK1021694	Flint Ridge RWD	1,300
OK1021773	GORE PWA	1,688
OK1021707	LRED (Chicken Creek)	302
OK1021731	LRED (Lakewood)	250
OK1021703	LRED (Wildcat)	250
OK1021727	LRED (Woodhaven)	200
OK1021702	Pettit MT Water	90
OK1021775	Sequoyah Co RWD 5	1,075
OK1020210	Sequoyah County Water Asso	15,719
OK1021701	Tahlequah PWA	18,431
OK1021745	Tenkiller Aqua Park	150
OK1021756	Tenkiller Utility Co	500
	Total	45,732

*Source: ODEQ SDWIS web site, http://sdwis.deq.state.ok.us/index.jsp
[a] Includes retail and wholesale population served

Water Treatment Used by Utilities in IRW

Water taken from the Illinois River and Lake Tenkiller is filtered under the requirements of the Surface Water Treatment Rule. Table 2 summarizes the treatment systems, chemicals used to treat water in the IRW and disinfectant residuals in these systems. Appendix B shows schematics for most of the water treatment plants in the IRW based on depositions taken from their operators and from documents provided by the utilities.

In general, conventional treatment (CONV) is used by most of the IRW utilities that have provided treatment information. CONV is characterized by use of a coagulant, some kind of mixing/flocculation, sedimentation (also called clarification) and filtration through a granular media filter (e.g. anthracite-sand). One advantage of this treatment method is that high concentrations of coagulant can be added to remove TOC from the water (in the sedimentation process) and reduce the formation potential of DBPs in the distribution system. Gore PWA uses direct filtration (DF) to treat its raw water which means that the system has all of the processes used in CONV except for the sedimentation basins. Levels of coagulant use in DF are limited due to the absence of a sedimentation process.

There is one modern membrane system in the IRW at Cherokee County RWD #13. Membranes have some significant advantages over the operation of more traditional CONV and DF systems. However, coagulants are not used in this system and membrane treatment plants are exempt from the TOC removal requirement under the Stage 1 DBPR. Slow sand filtration plants (SSF) which are used by LRED (Lakewood) and LRED (Woodhaven) are also not required to add coagulants and achieve required TOC removals.

Appendix B contains narrative descriptions of the treatment systems at the IRW utilities whose representatives were deposed during this litigation. The operators and managers that have been deposed clearly believe that the water they produce is safe to drink. All of the systems use chlorine as their only disinfectant. Compliance with the TTHM and HAA5 MCLs was easy for most of the utilities. Some of the utilities had problems with MCL compliance right after the Stage 1 DBPR was implemented, but they instituted relatively simple treatment adjustments such as moving the point of chlorination from the head of the plant to the clearwell at the end of the treatment processes. As will be discussed later, three of the utilities have had problems complying with DBP MCLs due to limitations of their treatment processes.

Table 2. Summary of Water Treatment in IRW Treatment Plants

Water Utility Name	Type of Treatment	Approximate Plant Capacity, mgd	Coagulant Used	Typical Coagulant Dose, mg/L	Disinfectant Used	Typical Disinfectant Dose, mg/L	Typical Disinfectant Residual Leaving Plant, mg/L	Typical Disinfectant Residuals in Distribution System, mg/L	Other Treatment Chemicals Used	Typical Dose, mg/L
Adair Co RWD 5										
Burnt Cabin RWD										
Cherokee CO 2 (Keys)	CONV	0.325	Omniflox Polymer	about 9	Chlorine	pre: 2-3; post 1-2	1.5-2.5	1-2	OWC 9204; phosphate	NA
Chrokee CO RWD 13	MEMBRANE	0.500	None	None	Chlorine	about 3	1-2.5	NA	None	None
East Central OK	CONV	about 0.3	Polymer	about 2	Chlorine	about 3	1.5-2	0.5-1	None	None
Fin Feather Resort										
Flint Ridge RWD										
GORE PWA	DF	about 0.3	Polymer	10-14	Chlorine	3-6	1-1.5	0.5-1	None	None
LRED (Chicken Creek)	CONV	0.288	3070C Polymer	Unknown	Chlorine	Unknown	2-3	0.5-1	None	None
LRED (Lakewood)	SSF	0.072	None	None	Chlorine	Unknown	2-3	0.5-1	None	None
LRED (Wildcat)	CONV	0.081	379S Polymer	Unknown	Chlorine	Unknown	2-3	0.5-1	None	None
LRED (Woodhaven)	SSF	0.108	None	None	Chlorine	Unknown	2-3	0.5-1	None	None
Pettit MT Water										
Sequoyah Co RWD 5										
Sequoyah County Water Asso	CONV	2	Polymer	6-12	Chlorine	2-3	1.5-2	1-1.5	Powdered Activated Carbon	0.4
Tahlequah PWA	CONV	8.7	Aluminum Chlorohydrate (WC2099); Polymer WC9900	20-40; 0.1	Chlorine	5-6	2-3	1.5-2.0	Sodium Permanganate; Fluoride	3; NA
Tenkiller Aqua Park										
Tenkiller Utility Co	CONV	about 0.05	Alum	12-20	Chlorine	2.5-4	1.5-2	0.5-1	Caustic Soda	10

Notes: SSF-Slow Sand Filter; CONV-Conventional; DF-Direct Filtration; MEMBRANE-Membrane Filters; NA-Not Available
Shaded cells = No data
Sources: Depositions of utilities, MORs, ODEQ SDWIS website

BASIS OF EXPERT OPINION #1—DISINFECTION BYPRODUCTS

Disinfection Byproducts Regulatory History

When chlorine and other disinfectants are added to drinking water to control microbial contaminants, these chemicals react with naturally occurring organic matter to produce a wide variety of trace organic compounds at ppb concentrations. The trace organic compounds resulting from reactions between disinfectants, inorganic bromide and natural organic matter (NOM) are generally referred to as disinfection byproducts (DBPs). The most prevalent DBPs in drinking water are trihalomethanes (THMs) and haloacetic acids (HAAs). THMs were discovered in drinking water by several researchers in 1974.

1979 Trihalomethane Regulation Leading to Recent DBP Rules

The first U.S. regulation to control THMs was promulgated in 1979. The 1979 THM rule recognized that regulating these DBPs presented a difficult problem compared to the regulation of other trace contaminants in drinking water. The addition of chlorine and other disinfectants to drinking water is crucial to the protection of public health. Since the first application of chlorine to U.S. drinking waters in 1908, typhoid fever and cholera have been eliminated in the U.S. by the careful application of these important chemicals. Thus, the regulation of THMs had to balance microbial safety with control of the health risks that were associated with DBPs. The 1979 THM regulation was thus completely different from other USEPA drinking water regulations which only had to balance the health risks and control of drinking water contaminants with the cost of those control measures.

The requirements of the 1979 THM regulation included quarterly sampling in water utility distribution systems and compliance with a total trihalomethane (TTHM) 0.10 mg/L maximum contaminant level (MCL) based on a running annual average of quarterly averages calculated from all distribution system samples. TTHMs were defined as the sum of the concentrations (in mg/L) of chloroform, bromodichloromethane, dibromochloromethane and bromoform. The MCL for TTHMs in the 1979 regulation is generally expressed as 100 μg/L or 100 ppb. For the utilities serving drinking water in the IRW, an important aspect of the 1979 THM regulation was that it only applied to utilities serving more than 10,000 people. All but two of the IRW utilities (in 1979 and currently) served less than 10,000 and were not regulated under the 1979 THM regulation. There were practical as well as public health reasons for not including smaller utilities in the 1979 THM regulation. The USEPA wanted the larger utilities to get experience balancing microbial and DBP health risks and to pass that experience on to smaller utilities as they were covered in later regulations. Without a clear understanding of how to control DBPs, there was a concern that small utilities might reduce chlorine doses to levels too low to protect against microbial diseases.

In the 1979 THM final regulation, the USEPA stated its intention to review the health effects of DBPs and further regulate this class of drinking water contaminants as more information became available. In November 1992, a series of meetings between the USEPA and affected stakeholders began which collectively became known as the microbial/DBP (or M/DBP) regulatory negotiation (Reg Neg). The Reg Neg process resulted in an Agreement in Principle between the stakeholders which laid the groundwork for the Stage 1 DBPR. Once again, the key feature of the agreement among the Reg Neg parties was a balancing of microbial and DBP risks. Costs were considered, but the primary focus of the Agreement in Principle and the Stage 1 DBPR was not to regulate DBPs to such low concentrations that the risks of waterborne microbial diseases would increase. In addition, more stringent regulation of surface water treatment by the Interim Enhanced Surface Water Treatment Rule complemented the control of DBPs.

The Agreement in Principle also specified that 18 months of DBP and microbial data would be collected from water utilities across the U.S. to form the basis of the Stage 2 DBPR (and to a limited extent the Stage 1 DBPR). Known as the Information Collection Rule (ICR), the data collection effort engaged thousands of regulatory and water utility personnel and cost more than $130 million.

The USEPA and stakeholders continued to meet in 1997 and 1999-2000 under the Federal Advisory Committee Act (FACA) which resulted in further agreements among the participants and final versions of the Stage 1 and Stage 2 DBPRs.

Information Collection Rule

The ICR was promulgated on May 14, 1996. As stated in a summary of the ICR: "The purpose of the ICR is to collect occurrence and treatment information to help evaluate the need for possible changes to the current SWTR [Surface Water Treatment Rule] and existing microbial treatment practices, and to help evaluate the need for future regulation for disinfectants and disinfection byproducts (D/DBPs)." Under the ICR, 296 water utilities across the U.S. serving more than 100,000 people participated in the data collection. Information was gathered on 500 water treatment plants operated by those utilities. Millions of pieces of data were collected during the period July 1997 to December 1998 (18 months). The ICR was the largest data collection effort of its kind ever conducted. Nationwide occurrence of THMs in distribution systems and source water total organic carbon (TOC) information were described in a book summarizing the ICR program (McGuire, McLain and Obolensky 2002).

Stage 1 DBP Rule

The Stage 1 DBPR established a number of new MCLs and revised the TTHM MCL. The MCL for TTHM was reduced from 100 ppb to 80 ppb. A new class of DBPs, haloacetic acids, was regulated. An MCL for five of the HAAs (HAA5) was established at 60 ppb. For large water utilities, the compliance calculation for these MCLs is exactly the same as the compliance calculation under the 1979 TTHM regulation--quarterly sampling in distribution systems and compliance based on a running annual average of quarterly averages calculated from all distribution system samples. As mentioned previously, the Stage 1 DBPR required first-time compliance with DBP MCLs for utilities serving fewer than 10,000 people. The Stage 1 DBPR was promulgated and published in the Federal Register on December 16, 1996.

Under the Stage 1 DBPR, the regulation of DBPs is based on risks associated with chronic diseases such as cancer. The risks are calculated based upon lifetime exposure to these compounds in drinking water. Thus, MCL compliance is based on averages over a one year period. Compliance with the Stage 1 DBPR MCL for THMs is NOT based on single values of THMs exceeding 80 ppb. Also, MCLGs and cancer risk numbers included in the language of the regulation were never intended to be considered as regulatory compliance levels. The reasons have already been stated: (1) health risks for DBPs must be balanced with health risks of waterborne microbial diseases, and (2) compliance is calculated over long periods of time because the health effects are chronic, requiring a long time of exposure before they may become evident.

Because the Stage 1 DBPR applies to all community water systems regardless of size, utilities in the IRW serving fewer than 10,000 people were regulated for DBPs for the first time. Monitoring to determine compliance with the rule was staggered over time, first, to apply to larger systems and, ultimately, to require monitoring for the smaller systems. The final implementation of the schedule of monitoring was left up to the primacy agencies—the states. Monitoring for compliance with TTHM and HAA5 MCLs by small systems in the IRW appears to have begun after 2002 (ODEQ 2008a).

Stage 2 DBP Rule

A full evaluation of the DBP data collected under the ICR indicated that utilities were complying with the MCLs for TTHM and HAA5 based on annual averages of quarterly data, but some utilities had very high DBP concentrations in parts of large distribution systems. Concerns were raised during the FACA meetings over shorter-term reproductive and developmental health effects for DBPs. This concern resulted in the FACA committee negotiating a change in how TTHM and HAA5 annual averages were calculated. The overall regulatory philosophy of the MCLs being based on chronic health effects was still maintained in the final Stage 2 rule. However, an effort in the final rule was made to address the possible short-term health effects.

The Stage 2 DBPR requires that all community water systems conduct additional DBP sampling at locations in their systems that tend to have high DBPs. The Initial Distribution System Evaluation (IDSE) will then followed by a revision to the monitoring locations under the Stage 2 rule that reflects these new, higher DBP locations.

A major difference between the Stage 1 and Stage 2 DBPRs is the calculation of the averages that are compared to the MCLs. The MCL values for TTHMs and HAA5 did NOT change between the two rules. Under Stage 2, the MCL value for TTHMs will still be 80 ppb and for HAA5 will still be 60 ppb. The basis of compliance for the Stage 2 DBPR MCLs for TTHM and HAA5 will continue to be an annual average calculation. Annual averages will be determined **for each sampling point** in the distribution system and compared to the MCLs instead of calculating annual averages from quarterly averages of all results from the distribution system. The new calculation method is called a Locational Running Annual Average (LRAA).

Therefore, MCL compliance with the Stage 2 DBPR will NOT be based on individual TTHM or HAA5 values. Nor will compliance with the regulation be determined by comparing individual TTHM or HAA5 values with MCLGs or calculated theoretical cancer risks.

The Stage 2 rule also requires utilities that experience short-term, high DBP levels to investigate why these concentrations have occurred and to report that information to the state regulatory agency. On page 392 of the Stage 2 DBPR preamble is stated:

> "3. Operational Evaluation Levels. The IDSE and LRAA calculation will lead to lower DBP concentrations overall and reduce short term exposures to high DBP concentrations in certain areas, but this strengthened approach to regulating DBPs will still allow individual DBP samples above the MCL even when systems are in compliance with the Stage 2 DBPR. Today's rule requires systems that exceed operational evaluation levels (referred to as significant excursions in the proposed rule) to evaluate system operational practices and identify opportunities to reduce DBP concentrations in the distribution system. This provision will curtail peaks by providing systems with a proactive approach to remain in compliance." (USEPA 2006)

The Stage 2 DBPR was promulgated on January 4, 2006 and does not become effective for any utility until well after 2012. For utilities serving fewer than 50,000 people, compliance with the TTHM and HAA5 MCLs is not required until after 2013. As of the date of my report, the DBP regulation in effect is the Stage 1 DBPR.

Oklahoma DBP Regulations

Oklahoma has primacy under the Stage 1 DBPR and implements the regulation as defined by the federal requirements. In calendar year 2007, ODEQ noted that there were 547 state-wide violations of the Stage 1 DBPR MCL by 125 systems (ODEQ 2008b). It appears that Oklahoma has not adopted the Stage 2 DBPR. Based on depositions of water utility personnel, the IRW utilities are working with the USEPA to get their IDSE monitoring plans approved.

Sources of DBP Precursors in Water Supplies

THMs and other DBPs are produced in drinking water treatment plants and in distribution systems as the result of complex chemical reactions between organic and inorganic substances in water and disinfectants (particularly chlorine) added to protect the public from waterborne diseases. The complex production of DBPs can be represented by the following simplified equation:

organic material + chlorine + inorganic bromide ==> trihalomethanes + haloacetic acids + other DBPs

Since the discovery of THMs in drinking water in 1974, researchers have been studying the types of organic materials that act as precursors in the DBP reaction. The organic material cannot be described as one unique organic compound (or even thousands of named organic compounds) nor is there one analytical method that completely characterizes the structure, identity or reactivity of the organic materials that act as DBP precursors. Many researchers in this field refer to all organic material in water as NOM although fractions of NOM may not be from "natural" sources. Other researchers have focused on humic substances to describe a large fraction of organic material in water:

> "The term *HUMIC SUBSTANCES* refers to organic material in the environment that results from the decomposition of plant and animal residues, but that does not fall into any of the discrete classes of compounds such as proteins, polysaccharides, and polynucleotides. Humic substances are ubiquitous, being found in all soils, sediments, and waters. Although these materials are known to result from the decomposition of biological tissue, the precise biochemical and chemical pathways by which they are formed have not been elucidated." (MacCarthy and Suffet 1989)

Within the last few years, researchers have identified another source of organic material in water supplies—effluent organic matter or EfOM—that can contribute to the formation of DBPs upon chlorination. EfOM is composed of degradation products of influent organic waste and soluble microbial products that consist of macromolecules and cellular remnants comprised of proteins and polysaccharides (Krasner et al. 2005; Krasner et al. 2006; Krasner 2006).

Figure 2 is from the work by Krasner and others and demonstrates the complexity of formation of EfOM during wastewater treatment.

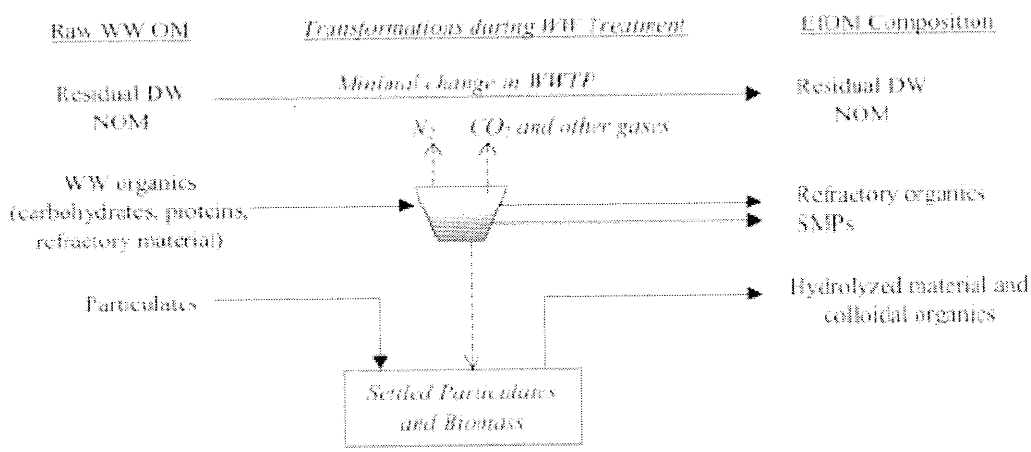

Figure 2. Generalized Fate and Composition of Organic Matter During Wastewater Treatment (Krasner et al. 2005)

There are a number of analytical methods that describe the general characteristics of DBP-reactive organic materials, including total organic carbon, dissolved organic carbon, UV absorbance at 254 nm, fluorescence, Specific Ultraviolet Absorbance (SUVA), assimilable organic carbon (AOC), biodegradable organic carbon (BDOC), simulated distribution system THMs (SDSTHMs) and THM formation potential (THMFP). Over the past 20-30 years, tests for the organic materials occurring in water supplies have been able to describe its more intricate characteristics, such as apparent molecular weight distribution (usually by membrane separation or gel permeation chromatography), polarity (by reverse phase liquid chromatography), and humic and fulvic acid fractions (by XAD resin separation) (Owen, Amy and Chowdhury 1993). In addition, there are the more traditional soil science methods for characterizing humic and fulvic acids and gross measures of proteins, carbohydrates and amino acids (Suffet and MacCarthy 1989).

Researchers in this field commonly describe a division of NOM into two classes: allochthonous (external sources) and autochthonous (internal sources). However, what does not exist is a methodology for definitively connecting the organic material in water to its sources or even into allochthonous and autochthonous categories. For example, there is no analytical method that separates out the fraction of TOC in a water sample into sources from which it originated, (e.g., decay of vegetative material (leaves, grasses, pine needles, wood, plants), hydrolysis of soil fractions, decay of animal tissues, algae and macrophyte growth (plus death and decay), organic transformations by many thousands of different kinds of microbes, discharges by industries and wastewater treatment plants, and non-point source discharges from agricultural operations). In their reports, the plaintiffs' experts have not recommended or used any analytical method which specifically identified organic molecules coming from field-applied poultry litter or from algal metabolism.

Figure 3 is a representation of the complexity of the sources of organic materials in the IRW. Comparing Figure 3 with Figure T1 in Teaf's report (Teaf 2008a), it is obvious that Teaf has grossly oversimplified how THMs and HAAs are produced. His oversimplification happens to support his contention that all of the DBPs produced by IRW water utilities are caused by poultry litter. There is no proof presented by the plaintiffs' experts that field applied poultry litter accounts for any of the DBP precursors in the IRW.

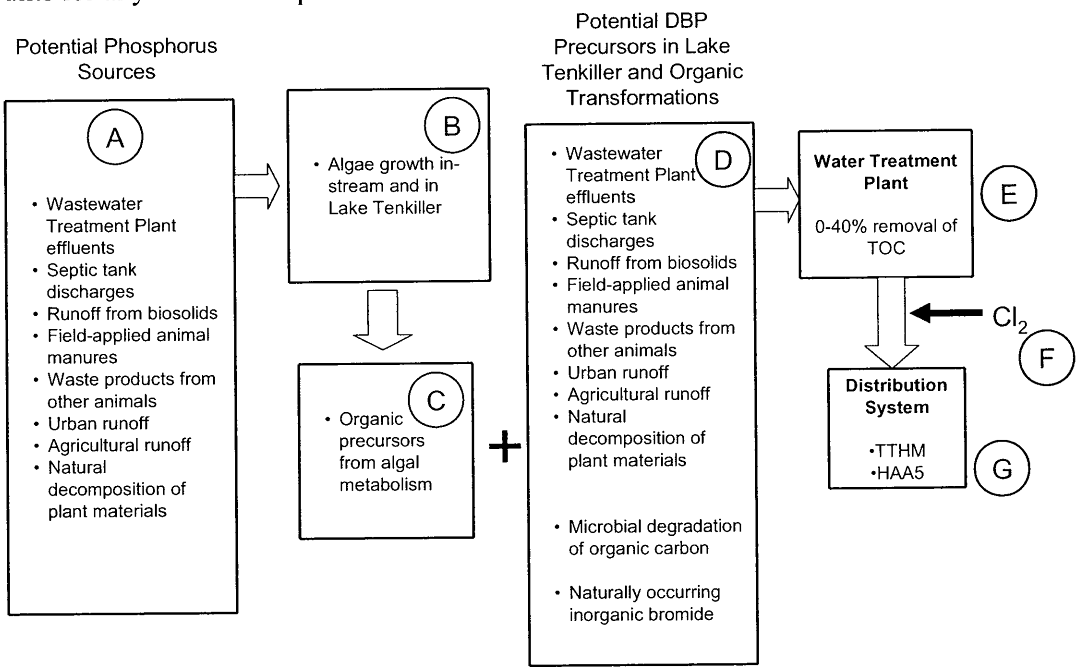

Figure 3. Corrected—TTHM/HAA5 Related to "Eutrophication"

A close examination of Figure 3 shows that it is impossible to associate any production of TTHM/HAA5 with any particular source of precursors. Step A on Figure 3 indicates that there are multiple possible sources of phosphorus (also, nitrogen) in the IRW. Nitrogen and phosphorus nutrients that end up in the streams feeding Lake Tenkiller and the Lake itself interact with sunlight, carbon dioxide and the algae already existing in Lake Tenkiller to produce more algae, Step B. Algae can produce organic compounds (Step C), some of which can interact with chlorine in the final step to produce DBPs. It is certainly not possible to identify which source of phosphorus results in the production of which fraction of algae-derived organic DBP precursors.

Algal precursors are part of the mix of other organic DBP precursors (Step D) that exist in Lake Tenkiller which are present in lake water along with inorganic bromide from natural sources. If tracking organic materials from the sources to their ultimate fate in a water body were not tough enough, microbial degradation of some fractions of the organic DBP precursors occurs in lake water and sediments which obliterates the identity of the organic material sources.

Water containing this complex mix of organic precursors is taken into a water treatment plant (Step E) where removal during coagulation-sedimentation-filtration treatment of a portion of these organic fractions results in a sub-set mix of organic precursors that is unrecognizable from both the original sources and from any microbially mediated changes that took place in the Lake.

Chlorine is then added during water treatment (Step F). Chlorine reacts with the inorganic bromide and **some** of the remaining fractions of organic material to produce THMs and HAAs. The regulatory required sampling and measurement of TTHM and HAA5 in the distribution system (Step G) is now completely unconnected to (and unknowable from) specific sources of organic material introduced into and changed within Lake Tenkiller. The oversimplified picture of sources of organic DBP precursors presented by Teaf (2008a) in his Figure T1 is clearly not correct.

IRW Utility TOC and DBP Data

In this section of my report, TOC and DBP data from IRW utilities will be presented and analyzed.

TOC Data from IRW Utilities

As part of their compliance with the Stage 1 DBPR, utilities treating surface water must collect monthly TOC data in the raw water (before any treatment) and in the finished water (after all treatment is complete). Depending on the treatment plant influent water quality, treatment plants must achieve TOC percent removals specified in a 3x3 matrix published in the Stage 1 DBPR or they must meet alternative compliance criteria. All monthly TOC data must be reported to ODEQ.

ODEQ has posted TOC data provided by the IRW water utilities on its SDWIS web site (ODEQ 2008a). Table 3 lists the 18 water utilities in the IRW along with their average raw water TOC levels and the period of record. Six utilities are apparently not required to routinely collect and submit TOC data (i.e., Cherokee Co RWD#13, Fin Feather Resort, LRED [Lakewood], LRED [Woodhaven], Petit MT Water and Tenkiller Aqua Park). To determine average TOC values, data that was obviously incorrect had to be removed from the data set. Any value over 5 mg/L was discarded unless there was additional information that supported its inclusion. A TOC of 5 mg/L represents data points beyond the 99th percentile for the IRW TOC data set. Table 3 shows that there is a rich TOC data set for the IRW utilities collected over several years. The overall average TOC for IRW utilities during the period of record was 1.9 mg/L.

Table 3. Summary of Raw Water TOC Data for IRW Utilities (ODEQ 2008a)

Utility Name	Average Raw Water TOC, mg/L	n	Period of Record
Adair Co RWD #5	0.8	47	12/3/2003--10/21/2008
Burnt Cabin RWD	2.2	57	11/6/2003--11/11/2008
Cherokee CO #2 (Keys)	2.2	57	10/16/2003--11/5/2008
Cherokee CO RWD #13	1.8	2	2/2/2004--2/24/2004
East Central OK	2.1	59	1/26/2004--11/17/2008
Fin Feather Resort	NA	NA	NA
Flint Ridge RWD	0.7	48	1/22/2004--10/7/2008
GORE PWA	2.0	58	2/5/2004--11/5/2008
LRED (Chicken Creek)	2.7	54	1/6/2004--11/5/2008
LRED (Lakewood)	NA	NA	NA
LRED (Wildcat)	2.1	59	1/6/2004--10/1/2008
LRED (Woodhaven)	NA	NA	NA
Pettit MT Water	1.4	3	1/26/2004--5/17/2004
Sequoyah Co RWD 5	2.2	58	1/20/2004--11/3/2008
Sequoyah County Water Asso	2.2	74	1/30/2002--11/5/2008
Tahlequah PWA	1.5	85	1/7/2002--11/5/2008
Tenkiller Aqua Park	NA	NA	NA
Tenkiller Utility	2.0	58	4/29/2004--10/22/2008
Overall Average	**1.9**		

NA = Data Not Available

All of the raw water and finished water TOC data from the 13 IRW utilities that collected TOC data (and limited data from two others) are plotted on graphs in Appendix C. The addition of coagulants and subsequent removal of particulates in the surface water treatment plants removed varying amounts of TOC. Also shown in Appendix C are the percent removal plots for TOC for the entire period of record. The percent TOC removal plots show that many of the utilities required a year or two to improve their TOC removal treatment processes and manage TOC sample collection and data reporting. Therefore, comparisons between utility TOC removal performances in my report will only be made using data from the period 2005 to 2008. Table 4 presents the average percent TOC removals for the IRW utilities that were required to monitor for TOC in their raw and finished waters under the Stage 1 DBPR during the period 2005 to 2008.

Table 4. TOC Average Percent Removals at IRW WTPs, 2005-2008 (ODEQ 2008a)

Utility Name	TOC Average Percent Removal 2005-2008
Adair Co RWD #5	4%
Burnt Cabin RWD	26%
Cherokee CO #2 (Keys)	33%
Cherokee CO RWD #13	NA
East Central OK	17%
Fin Feather Resort	NA
Flint Ridge RWD	2%
GORE PWA	22%
LRED (Chicken Creek)	20%
LRED (Lakewood)	NA
LRED (Wildcat)	19%
LRED (Woodhaven)	NA
Pettit MT Water	NA
Sequoyah Co RWD 5	27%
Sequoyah County Water Asso	40%
Tahlequah PWA	18%
Tenkiller Aqua Park	NA
Tenkiller Utility	40%

NA = Data Not Available

The graphs in Appendix C and the data on Table 4 show that there are widely different percent TOC removal efficiencies by the IRW water treatment plants. Overall, the best TOC removal performances were by Sequoyah County Water Association and Tenkiller Utility Co with average values of 40%. The least amounts of TOC removed were by Adair Co RWD #5 and Flint Ridge RWD.

Between these two extremes, TOC average removals ranged from 17 to 33 percent. Typical TOC removals were around 20%. Besides variations between the utilities, which will be discussed in a later section to be due to differences in treatment, there is significant variability for TOC removal within each treatment plant over time. During 2005 to 2008, Cherokee Co RWD #2 had an average TOC removal of 33%. During that same period, the TOC removal ranged from 2% (June 11, 2008) to 64% (January 17, 2007). Negative TOC removals shown on the graphs in Appendix C are a function of analytical or sampling errors. TOC is not added during a water treatment process. Outliers were removed from the TOC percent removal data sets due to wildly negative percent removals (up to minus 800%).

Comparison of IRW and ICR TOC Values

TOC Data for U.S. Water Utilities

As previously stated in my report, the ICR was a national drinking water data collection effort required by regulation and carried out over an 18 month period—July 1997 to December 1998. Under the ICR, 296 water utilities serving more than 100,000 people participated in the data collection, and information was gathered on 500 water treatment plants operated by those utilities.

Thousands of raw water samples were collected and analyzed for TOC as part of the ICR. The ICR was the first national survey of the organic carbon content of ground and surface water supplies in the U.S.

Figure 4 shows geographic distribution of ICR TOC data by state. Clearly, there are differences in TOC concentrations in water supplies across the U.S. The combined surface water and groundwater TOC data shown in Figure 4 indicate high (above average) TOC concentrations in Virginia, North Carolina, Florida, Mississippi, Oklahoma, Texas, and the Midwest (with a scattering of high values in New England). The two utilities that participated in the ICR from Oklahoma served Oklahoma City and Tulsa. Many parts of the U.S. contain much higher average levels of TOC as compared to the IRW utilities (average TOC = 1.9 mg/L). There is no evidence that poultry litter accounts for any of the high levels of TOC in other parts of the U.S.

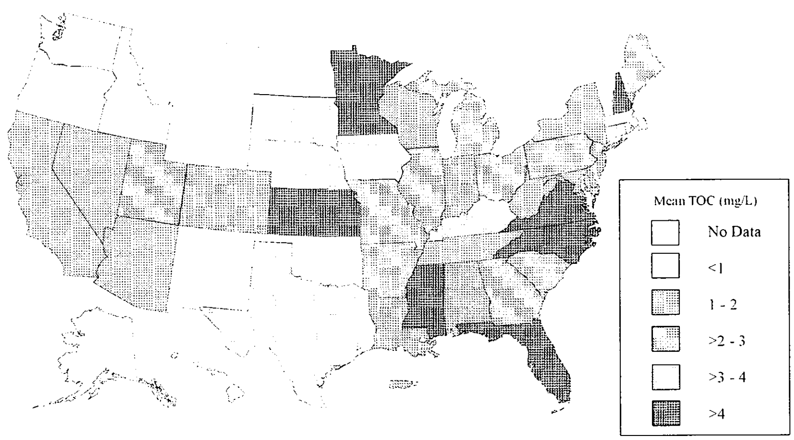

Figure 4. Geographic Distribution of National TOC Occurrence in Surface Water and Groundwater (McGuire and Hotaling 2002)

There are a variety of methods to compare different data sets in a graphical manner. Box and whisker plots are used in my report to summarize large amounts of data and illustrate both the central tendencies and variations about the means/medians of comparable data sets. Figure 5 is an example graphic showing a box and whisker plot with important parts of the data presentation labeled. The 90th percentile is the value below which 90 percent of the data in a data set can be found. Similarly, the 50th percentile (or the median) is where half of the data is greater than and half is less than that value. Very often, the average and the median values do not agree, especially if the data set contains a few very high values.

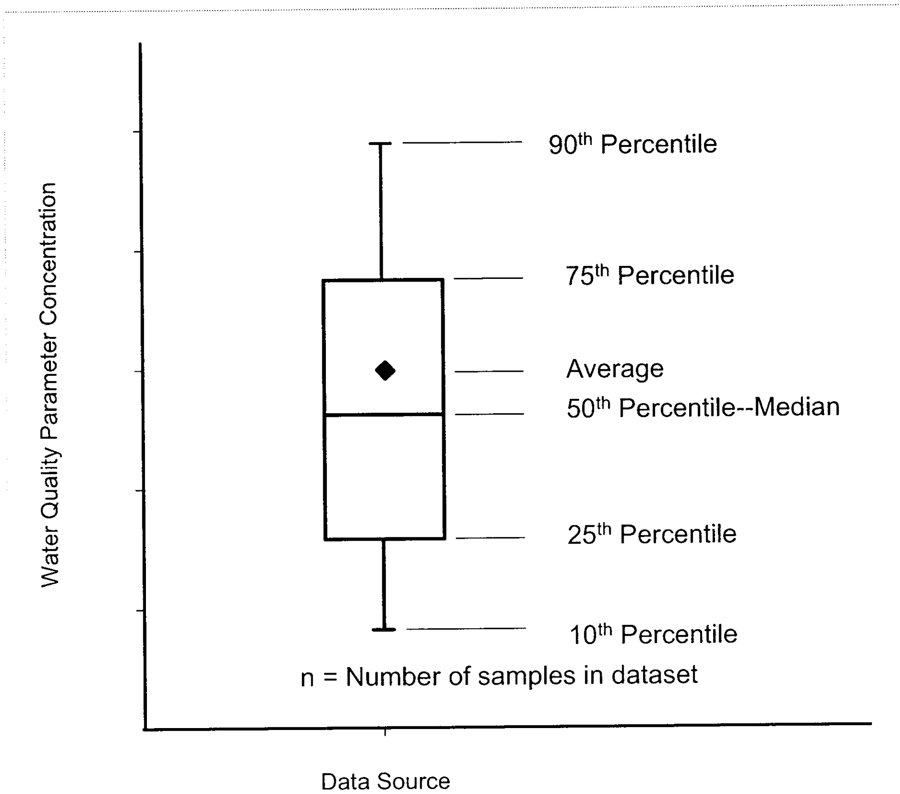

Figure 5. Explanation of Box and Whisker Plots

IRW and ICR TOC Data

It is useful to compare the occurrence of TOC in raw water samples from the IRW with the national data collected from the ICR to determine how different or similar IRW TOC data is from surface waters across the U.S. Figure 6 compares the raw water TOC data from the IRW utilities (ODEQ 2008a) with the TOC data collected during the ICR (McGuire and Graziano 2002). TOC levels in the raw water serving IRW water treatment plants appear to be lower than TOC levels in surface waters across the United States.

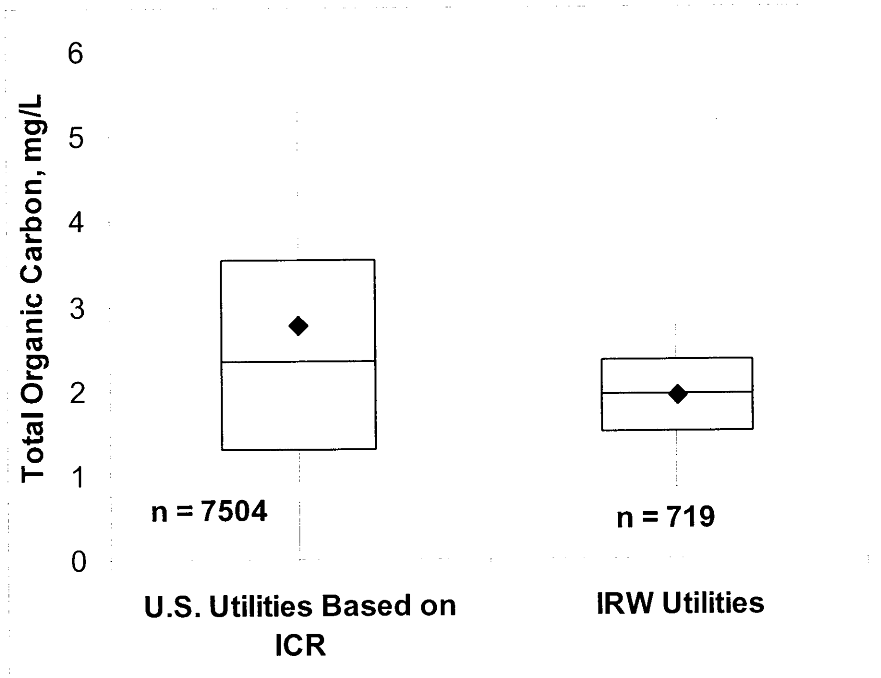

Figure 6. Comparison of Raw Water TOC Values Across the U.S. with Raw Water TOC Values in IRW Water Treatment Plant Influents

The average IRW TOC value was 1.9 mg/L and the average ICR TOC value was 2.8 mg/L. A Mann-Whitney U test found that there were significant differences between the two data sets ($p < 0.001$). The statistical difference matches the visual difference between the two data sets on Figure 6. The little variation about the mean and median and the much lower 90th and 75th percentiles for the IRW data are quite different from the wide variation in TOC values for the ICR data. TOC data from IRW utilities during the period 2002 to 2008 were less than TOC data collected nationwide from hundreds of utilities with thousands of data values.

DBP Data for IRW Water Utilities

Tables 5 and 6 summarize the entire period of record for the TTHM and HAA5 data on the ODEQ SDWIS website as of early December 2008 (ODEQ 2008a). The DBP data provided on the ODEQ SDWIS website are incredibly detailed, and the website contains the official State of Oklahoma data set for TTHM and HAA5 data for the 18 IRW utilities.

Tahlequah PWA has the longest period of record for DBP data in the IRW. Their quarterly TTHM data stretches back to 1997. HAA5 monitoring by Tahlequah PWA began in 1999. Sequoyah County Water Association has a long period of record for TTHM data extending back to 2000. Both of these utilities serve more than 10,000 people and have had to monitor for TTHMs for many years.

Most of the remaining utilities began monitoring for both TTHM and HAA5 in 2003 to 2004. The number of values on Tables 5 and 6 for Tahlequah PWA and Sequoyah County Water Association are high not only because of their long periods of record, but also because they are the only two utilities in the IRW that must take DBP compliance samples at four distribution system sampling locations under the Stage 1 DBPR. The rest of the utilities sample at one location in the distribution system with the longest residence time designated as DBPMX. Some of the larger small systems collect one DBPMX sample per quarter. The very smallest systems collect one sample per year at DBPMX corresponding to the highest water temperature (in the third quarter, July to September) and only convert to quarterly monitoring if their yearly sample exceeds 80 or 60 ppb for TTHM and HAA5, respectively.

There are wide variations in the overall distribution system averages for the IRW utilities which are driven by a number of factors including detention times in the distribution systems, efficiencies of TOC removal and chlorine addition practices (dose as well as point of application). TTHM averages ranged from 7.1 ppb (Adair Co RWD #5) to 70.9 ppb (Tenkiller Aqua Park). HAA5 averages ranged from 6.8 ppb (Adair Co RWD #5) to 63.9 ppb (East Central OK). Tables 5 and 6 also show that higher levels of TTHMs are produced compared to the concentrations of HAA5, which is typical for U.S. water utilities.

Table 5. Overall Average TTHM Data for IRW Utilities

Utility Name	Average Distribution System TTHM, ppb	n	Start Period of Record	End Period of Record
Adair Co RWD #5	7.1	14	12/3/2003	9/29/2008
Burnt Cabin RWD	38.0	9	11/6/2003	12/29/2007
Cherokee CO #2 (Keys)	56.2	23	3/15/2004	10/23/2008
Cherokee CO RWD #13	64.9	19	3/15/2004	10/23/2008
East Central OK	68.0	20	3/15/2004	11/18/2008
Fin Feather Resort	32.1	6	11/6/2003	8/25/2008
Flint Ridge RWD	18.1	15	3/30/2004	9/16/2008
GORE PWA	58.4	19	4/6/2004	11/5/2008
LRED (Chicken Creek)	22.4	11	7/13/2004	7/23/2008
LRED (Lakewood)	20.1	9	7/14/2004	7/23/2008
LRED (Wildcat)	21.1	7	7/14/2004	7/23/2008
LRED (Woodhaven)	54.8	11	7/13/2004	7/23/2008
Pettit MT Water	22.3	6	8/22/2006	6/18/2008
Sequoyah Co RWD 5	66.1	20	3/24/2004	11/12/2008
Sequoyah County Water Asso	53.6	138	6/13/2000	10/15/2008
Tahlequah PWA	49.4	164	2/12/1997	9/16/2008
Tenkiller Aqua Park	70.9	7	8/31/2004	9/15/2008
Tenkiller Utility	66.8	17	6/17/2004	5/29/2008
Overall Average	**49.8**			

NA = Data Not Available

Table 6. Overall Average HAA5 Data for IRW Utilities

Utility Name	Average Distribution System HAA5, ppb	n	Start Period of Record	End Period of Record
Adair Co RWD #5	6.8	13	3/30/2004	9/29/2008
Burnt Cabin RWD	33.6	9	11/6/2003	12/29/2007
Cherokee CO #2 (Keys)	37.8	23	3/15/2004	10/23/2008
Cherokee CO RWD #13	50.9	19	3/15/2004	10/23/2008
East Central OK	63.9	19	3/15/2004	11/18/2008
Fin Feather Resort	17.2	6	11/6/2003	8/25/2008
Flint Ridge RWD	8.4	15	3/30/2004	9/16/2008
GORE PWA	58.7	19	4/6/2004	11/5/2008
LRED (Chicken Creek)	12.3	11	7/13/2004	7/23/2008
LRED (Lakewood)	17.1	9	7/14/2004	7/23/2008
LRED (Wildcat)	22.9	7	7/14/2004	7/23/2008
LRED (Woodhaven)	44.4	11	7/13/2004	7/23/2008
Pettit MT Water	5.5	4	8/22/2006	6/18/2008
Sequoyah Co RWD 5	42.5	20	3/24/2004	11/12/2008
Sequoyah County Water Asso	25.4	84	10/7/2003	10/15/2008
Tahlequah PWA	33.4	124	10/25/1999	9/16/2008
Tenkiller Aqua Park	41.1	7	8/31/2004	9/15/2008
Tenkiller Utility	40.3	15	6/17/2004	5/29/2008
Overall Average	**33.1**			

NA = Data Not Available

Appendix D contains graphs of TTHM and HAA5 data based on the same period of record designated in Tables 5 and 6 for each of the 18 IRW utilities. One to three graphs are presented for each utility. One graph shows the quarterly (or, in some cases, yearly) values for both TTHM and HAA5. The other two graphs depict the Running Annual Average (RAA) values for TTHM and HAA5 calculated over the period of record. In some cases there were missing quarterly data. Best engineering judgment was used by me to calculate representative RAA values. For small utilities where RAAs could not be calculated, only the quarterly (or yearly) graphs are presented.

DBP MCL Compliance for IRW Utilities

Using improper and incorrect methods (to be explained in a later section) of calculating compliance with TTHM and HAA5 MCLs, Dr. Cooke and Dr. Welch (page 2 of their report) came up with an incorrect assessment of Stage 1 DBPR violations: "Commonly 20-30% of tap water samples from Tenkiller water had disinfection by-products in excess of USEPA standards." (Cooke and Welch 2008a) It is useful to determine the real percentage of MCL violations using the Stage 1 DBPR as the basis for calculation. Table 7 lists the 18 utilities using the IRW as a source of water. The numbers of "quarters" that each utility violated an MCL are listed in the second and third columns. The data in the second column was determined from the RAA graphs in Appendix D by totaling the running annual averages of quarterly TTHM and HAA5 data that exceeded the MCLs of 80 and 60 ppb, respectively. The violation numbers in the third column were summed directly from the ODEQ SDWIS website. For both calculations, if both MCLs were violated in a quarter, that situation was counted as one quarter of violation. Also, a quarter was counted as a violation quarter if either the TTHM or the HAA5 MCL was exceeded in that quarter.

Table 7. Summary of Stage 1 DBPR MCL Violations for IRW Utilities

Utility Name	Number of Quarters of MCL Violations Based on RAAs of TTHM HAA5 >MCL	Number of Quarters of MCL Violations Based on ODEQ SDWIS Website*	Total Number of Quarters of Data	Percent Violations Based on TTHM HAA5 >MCL	Percent Violations Based on ODEQ SDWIS Website
Adair Co RWD #5	0	0	14	0.0%	0.0%
Burnt Cabin RWD	0	0	9	0.0%	0.0%
Cherokee CO #2 (Keys)	0	0	17	0.0%	0.0%
Cherokee CO RWD #13	6	4	17	35.3%	23.5%
East Central OK	9	9	17	52.9%	52.9%
Fin Feather Resort	0	0	6	0.0%	0.0%
Flint Ridge RWD	0	0	12	0.0%	0.0%
GORE PWA	9	3	16	56.3%	18.8%
LRED (Chicken Creek)	0	0	12	0.0%	0.0%
LRED (Lakewood)	0	0	9	0.0%	0.0%
LRED (Wildcat)	0	0	7	0.0%	0.0%
LRED (Woodhaven)	1	1	11	9.1%	9.1%
Pettit MT Water	0	0	4	0.0%	0.0%
Sequoyah Co RWD 5	0	0	20	0.0%	0.0%
Sequoyah County Water Asso	0	4	32	0.0%	12.5%
Tahlequah PWA	0	0	42	0.0%	0.0%
Tenkiller Aqua Park	0	0	7	0.0%	0.0%
Tenkiller Utility	2	3	16	12.5%	18.8%
Totals	27	24	268	10.1%	9.0%

NA = Data Not Available
* As of 12/29/08

Depending on which data source is used to calculate violations, three of the IRW utilities account for 67 to 92 percent of the Stage 1 DBPR MCL violations (i.e., Cherokee Co RWD #13, East Central OK and Gore PWA). As stated before in my report, these three utilities are not practicing effective TOC removal and they are applying chlorine at the beginning of the treatment process before TOC is removed. Figure 1 shows that Cherokee Co RWD #13 is just across the lake from LRED (Lakewood) and just north of LRED (Chicken Creek) on the east shore of Lake Tenkiller. Neither of those utilities have DBP compliance problems. Gore and East Central OK draw water out of Lake Tenkiller near the dam, but so does Sequoyah Co Water Authority. Sequoyah Co Water Authority now has no trouble meeting the TTHM and HAA5 MCLs. It is not the source water quality that is causing the three utilities to fail to comply with the Stage 1 DBPR. They are not complying with the current DBP regulation because they are not treating the water efficiently. Compliance by the other IRW utilities demonstrates that compliance with the DBP regulation is not only possible, but routine.

The four violations for Sequoyah County Water Association were very early in its DBP compliance sampling history. Moving its point of chlorine application and improving removal of TOC solved its DBP compliance problems. All of the calculated RAAs for Sequoyah County Water Association are well below the MCLs (see Appendix D). The MCL violations by Tenkiller Utility Company were at the beginning of its compliance sampling. That utility adjusted its treatment by moving the point of chlorination. Tenkiller Utility Company has been in compliance with the Stage 1 DBPR since they made that treatment change.

ODEQ requires that utilities inform their customers of any MCL violations either in local media or as part of each utility's required annual CCR. The DBP MCL violations on the ODEQ SDWIS website do not always track with the RAA MCL violations noted in Table 7 due to a number of reasons including lapses in monitoring and different methods of calculating RAAs.

Table 7 also notes the numbers of quarters of data on which the percent DBP MCL violations are calculated. For very small utilities, only one annual sample is required to be collected at a point in the distribution system with the maximum residence time (DBPMX). Only if that annual value is greater than the MCL does the utility have to collect quarterly data at the DBPMX location. Several examples of increases to quarterly monitoring from yearly monitoring can be found in Appendix D (e.g., Burnt Cabin RWD, LRED (Lakewood), Tenkiller Aqua Park). For these very small utilities, a violation of the MCL can only occur if the RAA of the four quarterly values exceeds the MCL value (for TTHM or HAA5).

Therefore, the total violations of the DBP MCLs by the IRW utilities are 9 to 10% and not the 20% to 30% stated by Teaf (2008a) and Cooke and Welch (2008a). Obviously, all of the utilities in the IRW should strive to be 100% compliant with all primary drinking water standards. The low percent violation for the IRW utilities can best be put into perspective by comparing these data to other MCL DBP compliance data throughout Oklahoma.

Gibb (2008) in his expert report captured the context of IRW DBP MCL violations when he compared them to DBP MCL violations in other parts of Oklahoma where there is no apparent concern with the application of poultry litter to fields.

> "There is no evidence that DBP violations occur to any greater extent in the IRW than any other place in Oklahoma. Percentages of drinking water systems in violation of the MCLs for DBPs are presented for all counties in Oklahoma for the years 2004-2007 in Figure 13. As illustrated, DBP violations in the counties of the IRW are among the lowest across the state. When the number of systems having DBP violations are presented by zip code (Figures 14), the same pattern emerges (ODEQ 2008b, 2008c, 2007, 2006b, 2005)." (all references refer to Gibb's report)

Assessment of DBP Production by IRW Utilities

Table 8 summarizes the treatment plant information already presented in Table 3 and Appendix B with TOC information from Table 4 and Appendix C as well as the production of TTHM and HAA5 in the 2005 to 2008 time frame (Appendix D).

Table 8. Comparison of Treatment Efficiencies and DBP production by IRW Utilities

Water Utility Name	Type of Treatment	TOC Average Percent Removal 2005-2008	Typical Disinfectant Dose, mg/L	Typical Disinfectant Residual Leaving Plant, mg/L	Typical Disinfectant Residuals in Distribution System, mg/L	Average TTHM 2005-2008, ppb	Average HAA5 2005-2008, ppb
Adair Co RWD 5		4%				7	5
Burnt Cabin RWD		26%				29	21
Cherokee CO 2 (Keys)	CONV	33%	pre: 2-3; post 1-2	1.5-2.5	1-2	56	36
Chrokee CO RWD 13	MEMBRANE	near zero	about 3	1-2.5	NA	61	41
East Central OK	CONV	17%	about 3	1.5-2	0.5-1	70	60
Fin Feather Resort						31	16
Flint Ridge RWD		2%				19	9
GORE PWA	DF	22%	3-6	1-1.5	0.5-1	57	57
LRED (Chicken Creek)	CONV	20%	Unknown	2-3	0.5-1	15	12
LRED (Lakewood)	SSF	low	Unknown	2-3	0.5-1	11	10
LRED (Wildcat)	CONV	19%	Unknown	2-3	0.5-1	14	18
LRED (Woodhaven)	SSF	low	Unknown	2-3	0.5-1	47	39
Pettit MT Water						20	3
Sequoyah Co RWD 5		27%				67	44
Sequoyah County Water Asso	CONV	40%	2-3	1.5-2	1-1.5	47	25
Tahlequah PWA	CONV	18%	5-6	2-3	1.5-2.0	57	34
Tenkiller Aqua Park						74	45
Tenkiller Utility Co	CONV	40%	2.5-4	1.5-2	0.5-1	55	27

Notes: SSF-Slow Sand Filter; CONV-Conventional; DF-Direct Filtration; MEMBRANE-Membrane Filters; NA-Not Available
Grey Shaded cells = No data
Yellow Shaded cells = Significant number of MCL violations have occurred for these utilities
Sources: Depositions of utilities, MORs, ODEQ SDWIS website

As stated in the previous section, three of the utilities account for 67 to 92 percent of the Stage 1 DBPR MCL violations (i.e., Cherokee Co RWD #13, East Central OK and Gore PWA).

Cherokee Co RWD #2, Sequoyah County Water Assoc. and Tenkiller Utility Co. have demonstrated excellent removal of TOC using conventional treatment. High TOC removal for these utilities during 2005 to 2008 has translated into TTHM and HAA5 values well below the MCLs.

Chlorine residuals for the IRW utilities are higher than I am used to seeing in other utilities in the U.S. A disinfection survey of U.S. water utilities published in 2008 noted that the average and median free chlorine residuals leaving the plants were both 1.0 mg/L (Disinfection Systems

Committee 2008). Concentrations at the WTP finished water for IRW utilities (Table 8) are double or triple the 1.0 mg/L level. The reason for the high chlorine residuals leaving the IRW WTPs is due to an Oklahoma regulation that is more stringent than the USEPA requirement for chlorine levels under the SWTR. On page 4 of the current Oklahoma drinking water regulations (ODEQ 2008c) is the requirement:

> "(c) Chlorine. (1) The minimum free chlorine residual at the most distant points in a water distribution system must be 0.2 mg/L. (2) Free chlorine residuals must be at least 1.0 milligrams per liter at the POE [point of entry]."

The federal SWTR only requires that the minimum residual leaving the treatment plant be 0.2 mg/L and that a "detectable" disinfectant residual be measurable in 95% of distribution system samples. Undoubtedly, the Oklahoma chlorine residual requirements lead to higher DBP levels in Oklahoma utilities compared to other utilities in the U.S. that are under the federal SWTR requirements.

While Tahlequah PWA has never violated a DBP MCL, it could further reduce its DBP production by dramatically reducing the amount of chlorine added from about 5 to 6 mg/L to about 3 mg/L (depending on chlorine demand and water temperature). The maintenance of chlorine residuals in the distribution system of 1.5 to 2 mg/L by Tahlequah PWA results in higher than necessary DBP levels as well as customer complaints of chlorinous taste and odor problems.

Therefore, non-compliance with the Stage 1 DBPR in the IRW is primarily a function of three utilities not removing sufficient TOC in their treatment plants plus applying high doses of chlorine in non-optimal locations (e.g., at the beginning of the plant). Cherokee Co RWD #13 will continue to have problems meeting the Stage 1 DBPR (as well as future problems complying with the Stage 2 DBPR) if they do not implement a TOC removal process (such as GAC or enhanced coagulation) or convert to an alternate disinfectant such as chloramines. Their selection of membrane treatment (with little to no TOC removal) for their new treatment facility did not give them the same TOC control tools that other utilities have had in the IRW that use conventional treatment. East Central OK can dramatically improve its compliance performance if it optimizes its coagulant doses and moves its point of chlorination to after the filters as most of the other IRW utilities have done. Gore PWA needs to reduce its high chlorine doses, add a sedimentation basin to its treatment train and increase coagulant doses to remove more TOC prior to the addition of chlorine. Gore PWA's practice of applying chlorine "in the filters" is not optimum and could be changed to applying it after filtration which will result in low DBPs leaving the treatment plant.

Comparison of IRW and ICR TTHM Values

Figure 7 compares the TTHM data from surface water utilities collected during the ICR (McGuire and Graziano 2002) with the TTHM data from the IRW utility distribution systems (ODEQ 2008a). Based on the box and whisker plots, distribution system TTHM values in the treated water serving IRW customers do not appear to be distributed much differently from TTHM levels in water utilities across the United States. There appear to be small differences between the interquartile ranges for both data sets. However, a Mann-Whitney U test found that there were statistically significant differences between the two data sets, which do not appear reasonable given the distribution of data shown on Figure 7. The statistical difference in medians is most likely due to the higher levels of chlorine used by Oklahoma utilities compared to other utilities in the U.S.

As already described in my report, the ICR was conducted during July 1997 to December 1998. Most of the IRW TTHM data was collected during the period 2002 to 2008. It is my professional opinion that the ICR data shown on Figure 7 still represents a reasonable picture of DBP occurrence in the U.S. When the ICR was conducted, a number of utilities had already made treatment changes in anticipation of the Stage 1 DBPR that was being promulgated at that time. Further changes implemented to comply with the Stage 1 DBPR likely only affected the TTHM values above the 90th percentile (the top of the whisker on Figure 7). As a further indication that mean and median TTHM levels have not changed much since the ICR, the recent disinfection survey (Disinfection Systems Committee 2008) showed that finished water mean and median TTHM and HAA5 levels were essentially unchanged from 1998 to 2008. The same disinfection survey also showed no change in the mean/median chlorine concentrations leaving water treatment plants from 1998 to 2008—1.0 mg/L for both statistics.

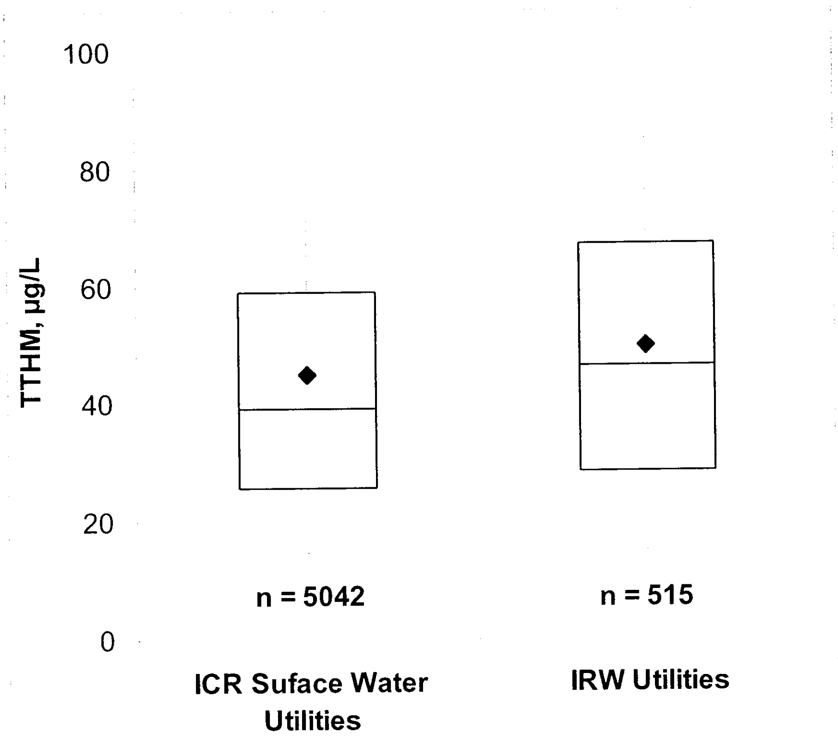

Figure 7. Comparison of Distribution System TTHM Values (Surface Water Sources) Across the U.S. with TTHM Values in IRW Distribution Systems

How representative are the ICR data for U.S. TTHM distributions after the Stage 2 DBPR is fully in effect? My opinion, based on years of experience with national compliance of DBP regulations, is that it is not possible to know the answer with great accuracy. The main impact of the Stage 2 DBPR will likely be in the top 10% of the TTHM data (above the top "whisker" on the box and whisker plot). The Stage 2 DBPR is designed to shave off the highest TTHM concentrations by calculating compliance based on a running annual average at each monitoring location—the LRAA. As stated previously in my report, the Stage 2 DBPR MCLs for TTHM and HAA5 are remaining the same, 80 and 60 ppb, respectively.

The box and whisker plot for the IRW data on Figure 7 somewhat overstates the TTHM average during the period of record for this data. During 2002-2004, many of the IRW utilities were, for the first time, sampling and analyzing for DBPs. Some of the DBP levels in the early quarters and years of sampling were very high. Early utility concern with Stage 1 DBPR violations, treatment changes plus operator experience resulted in much lower TTHM levels after the initial period (e.g., Tenkiller Utility Co and Sequoyah Co Water Authority).

It is my professional opinion that the TTHM data sets for ICR utilities and IRW utilities during the period 2002 to 2008 as shown on Figure 7 are very close. **As noted previously, TOC values in the IRW were significantly lower than ICR TOC values.** It is also my professional opinion that the higher chlorine residuals required by Oklahoma are reacting with the lower TOC concentrations in the IRW treated water which causes the IRW utilities to have slightly higher TTHM levels than the ICR utilities.

As stated previously in my report, DBP precursors come from a variety of sources. Also, when chlorine is added, differing amounts of TTHMs are produced depending on pH, temperature, contact time and chlorine dose. The levels of TTHMs produced by IRW utilities are slightly higher but not unusual when compared to TTHMs from other U.S. utilities.

Comparison of IRW and Oklahoma DBP Values

Figures 8 and 9 compare TTHM and HAA5 data from IRW utilities with all surface water utilities in Oklahoma (data for Oklahoma downloaded January 2009, ODEQ 2008a). Oklahoma surface water utility data is from the entire period of record found on the ODEQ SDWIS website. Both figures show that the levels of TTHM and HAA5 in all Oklahoma utilities using surface water are much higher than the DBP data from IRW utilities.

Average TTHM values for Oklahoma and IRW utilities were 74 and 50 ppb, respectively. Average HAA5 values for Oklahoma and IRW utilities were 44 and 33 ppb, respectively. Mann-Whitney U tests found that there were significant differences between the two data sets ($p < 0.001$) for both TTHM and HAA5 data. There are far greater problems with DBPs in the rest of Oklahoma as compared to DBPs in utilities in the IRW. Some of the TTHM values for Oklahoma surface water utilities were astonishingly high. Sixty-seven TTHM values in the Oklahoma data set were **above 300 ppb**. Two Oklahoma TTHM values were **above 800 ppb**. No data has been presented by the plaintiffs' experts that poultry litter is spread on fields in all water supply watersheds in Oklahoma outside of the IRW.

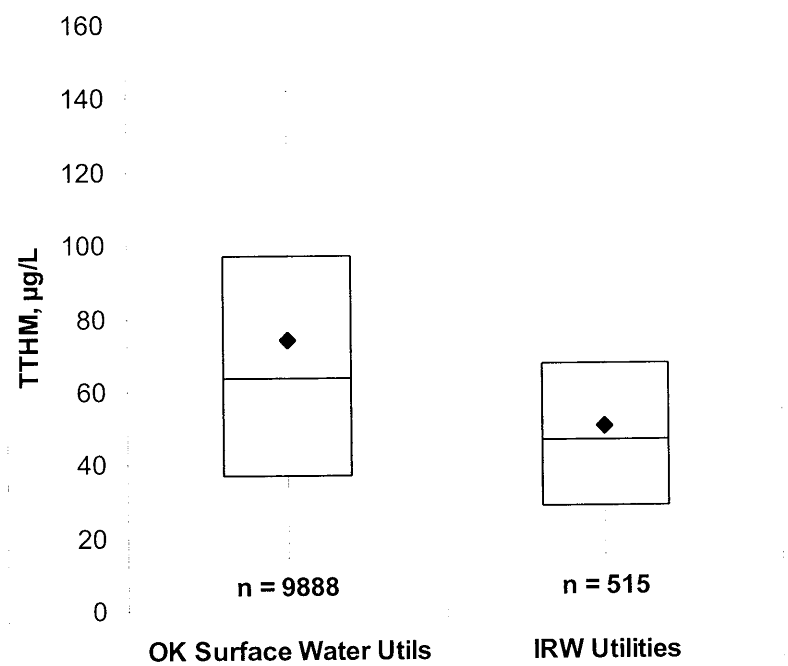

Figure 8. Comparison of Distribution System TTHM Values Between IRW Utilities and All Surface Water Utilities in Oklahoma (ODEQ 2008a)

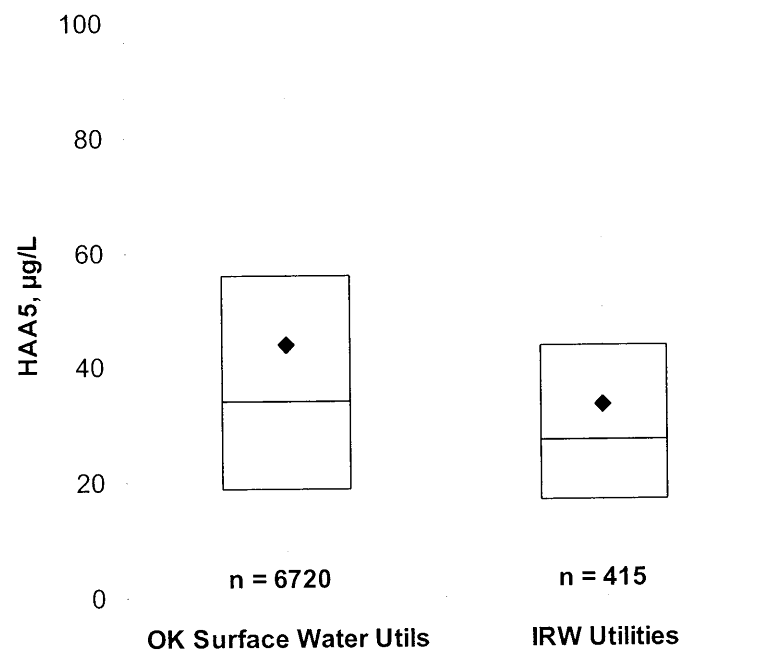

Figure 9. Comparison of Distribution System HAA5 Values Between IRW Utilities and All Surface Water Utilities in Oklahoma (ODEQ 2008a)

Potential Impact of Stage 2 DBPR on IRW Utilities

As stated several times already, the Stage 2 DBPR MCLs are the same as the MCLs in Stage 1. Figures 10 to 13 show the LRAA values calculated on **historical data** from the two large utilities in the IRW with long periods of record—Sequoyah Co Water Assoc and Tahlequah PWA. These utilities are large enough so that they must sample four locations in their distribution systems every quarter. LRAAs were calculated for locations DBP01, DBP02, DBP03 and DBPMX for both utilities. I must emphasize at this point that the Stage 2 DBPR is NOT in effect for these two utilities. The data on these four figures show that with the most recent history of DBP compliance, the two utilities would not have problems complying with the Stage 2 DBPR at these sampling locations. Because both of these utilities must conduct IDSE monitoring, other sampling locations may ultimately be selected for Stage 2 monitoring. However, it is my expert opinion that both utilities will be able to comply with the Stage 2 DBPR.

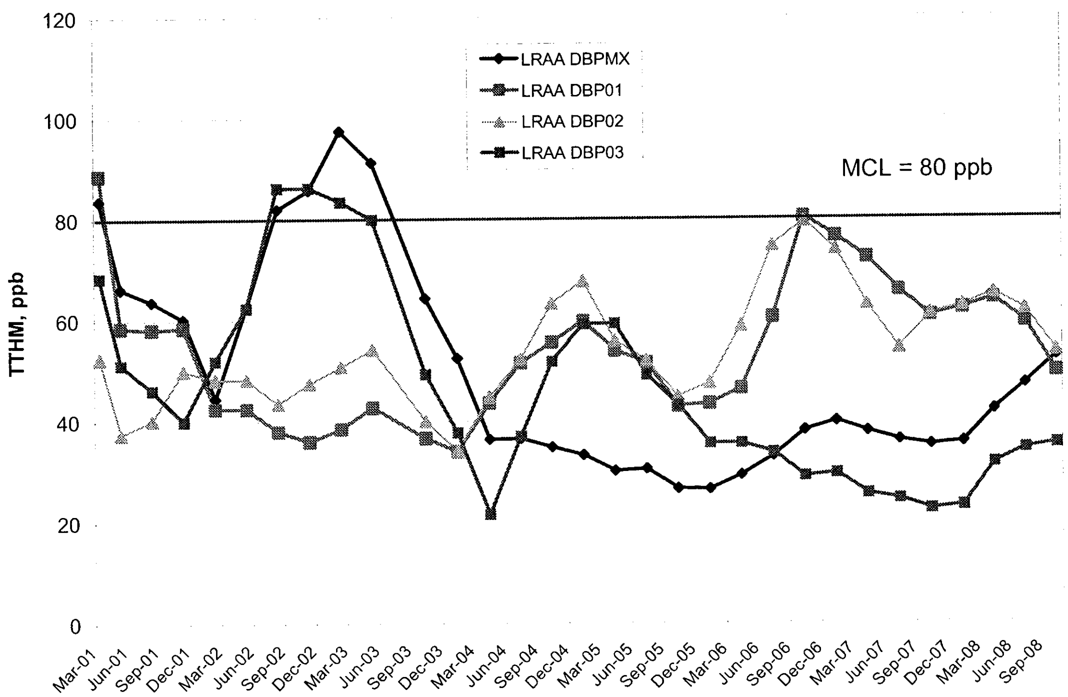

Figure 10. Calculated LRAA Values for Historical Sequoyah Co Water Assoc TTHM Data

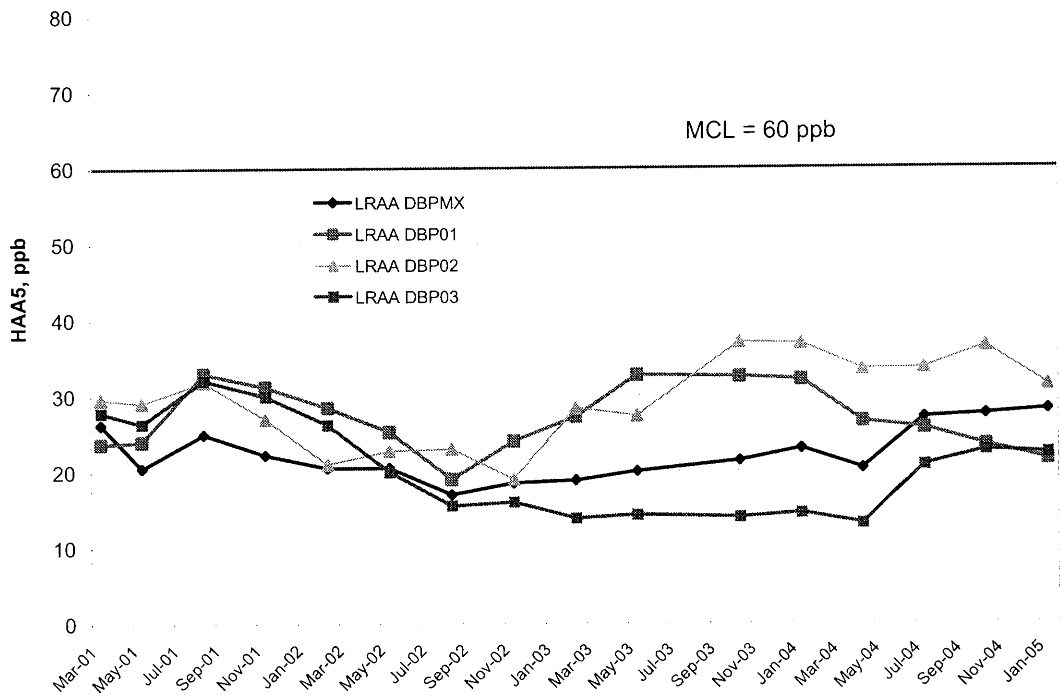

Figure 11. Calculated LRAA Values for Historical Sequoyah Co Water Assoc HAA5 Data

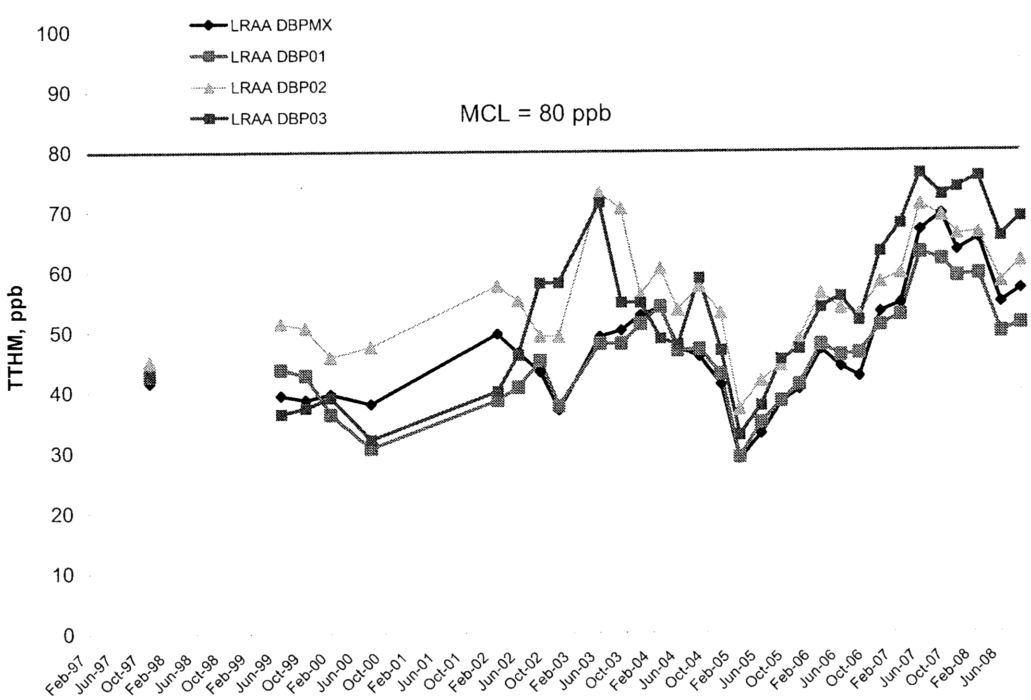

Figure 12. Calculated LRAA Values for Historical Tahlequah PWA TTHM Data

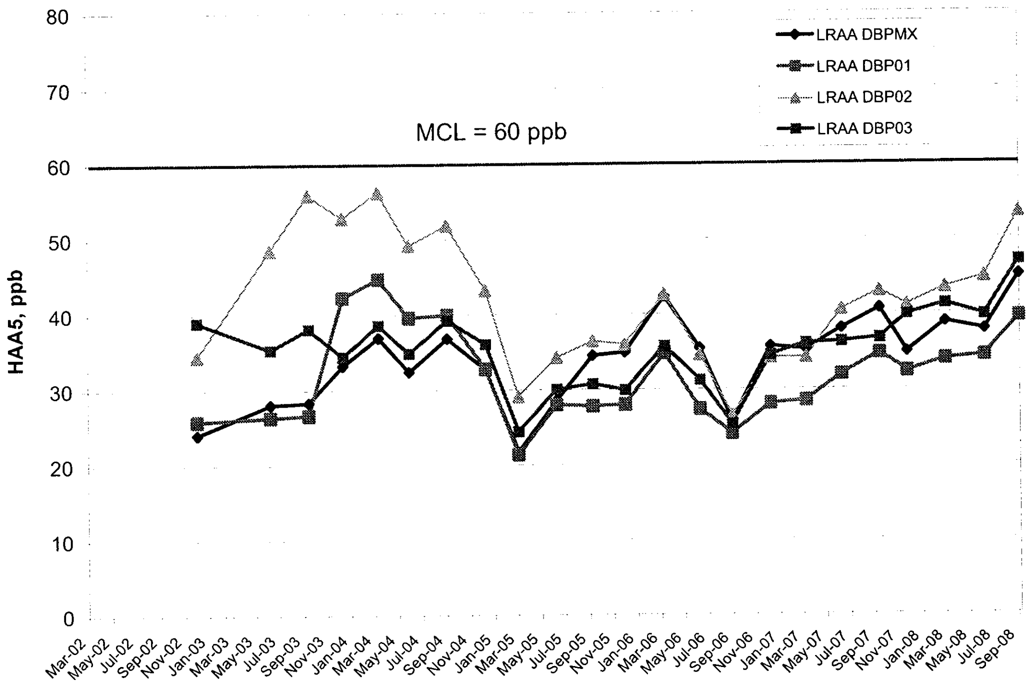

Figure 13. Calculated LRAA Values for Historical Tahlequah PWA HAA5 Data

For the small utilities in the IRW, there will be some important Stage 2 DBPR differences in their sampling and compliance calculations. Under the Stage 1 DBPR, many of the smaller IRW utilities collect one sample per quarter from what is designated as the DBPMX (or maximum DBP) location. In essence, they are already complying with the Stage 2 regulation as long as their LRAA values at DBPMX stay below 80 and 60 ppb.

One of the changes for the small utilities (serving 500 to 3,300 people) under Stage 2 is that they must pick monitoring locations representing maximum TTHM and maximum HAA5 values. If both maximum values are found at the same location, only one monitoring point is required. Given the quality of water in the IRW and the potential to produce DBPs from it, it is my opinion that in most cases, the small utilities will be sampling only one location for both TTHM and HAA5 compliance under the Stage 2 DBPR—just as they have been doing under Stage 1. In addition, small utilities cannot move from quarterly monitoring to only monitoring once per year unless their DBP levels are half of the MCLs, which will probably not apply to IRW utilities.

Even with these monitoring changes, it is my opinion that there will not be compliance problems with IRW utilities under the Stage 2 DBPR except for the three utilities that do not employ an effective TOC removal treatment process (i.e., Cherokee Co RWD #13, East Central OK and Gore PWA). The 15 utilities that generally have complied with the Stage 1 DBPR have several years of experience complying with that regulation and they understand what needs to be done to optimize treatment and reduce DBPs (e.g., move point of chlorination, reduce excessive use of chlorine, increase coagulant dose to remove DBP precursors). The three utilities not practicing effective DBP precursor removal will have to begin removing TOC effectively and to use chlorine judiciously or they will remain in violation of a primary drinking water regulation.

Broken Bow TOC and DBP Data

Information on Broken Bow Reservoir and Broken Bow PWA

Broken Bow Reservoir is located in McCurtain County in southeastern Oklahoma, see Figure 14. The lake is 22 miles long and covers 14,200 acres. It has a mean depth of 64.7 feet and a watershed area of 754 square miles.

Raw water quality in Broken Bow Reservoir can be characterized as relatively high in TOC and very low in alkalinity (e.g., 10 mg/L as $CaCO_3$) and low to moderate levels of turbidity (1-2 NTU).

Only one community water system withdraws water from Broken Bow Reservoir—Broken Bow PWA (BBPWA). BBPWA serves 4,231 retail and 11,055 wholesale customers (ODEQ 2008a). BBPWA wholesales water to a number of smaller water utilities serving McCurtain County.

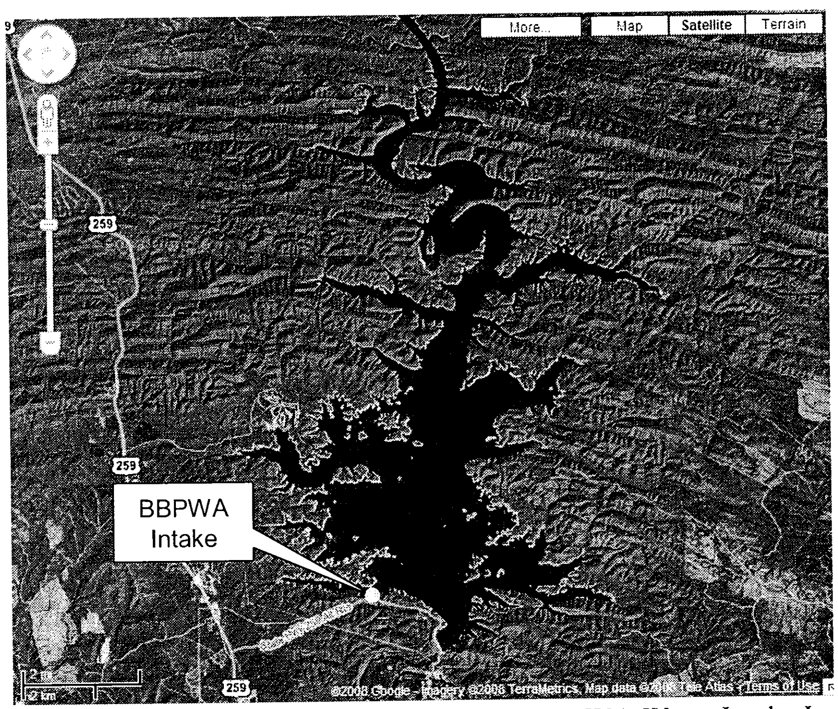

Figure 14. Broken Bow Reservoir and Broken Bow PWA Water Intake Location

Broken Bow Reservoir TOC Data

In Appendix E, a graph shows the TOC data for the period of record that was obtained from the ODEQ SDWIS website (ODEQ 2008a). The overall average raw water TOC is 2.7 mg/L and the graphs in Appendix E show measurable removal of TOC by the water treatment plant since 2001. However, Broken Bow PWA has been cited ten times in the last seven years by ODEQ for "Inadequate DBP Precursor Removal." The required TOC removal under the Stage 1 DBPR for BBPWA WTP is 35%.

Water Treatment by Broken Bow PWA

The raw water intake for the BBPWA treatment plant is located on the spillway at the southern end of the reservoir a little over one mile from the BBPWA WTP, see Figure 14. The BBPWA treatment plant employs CONV treatment. Appendix E contains a schematic of the current water treatment processes and a narrative description of the treatment plant. Chlorine is used as the primary disinfectant in the treatment plant. Table 9 summarizes the water treatment information and chemicals used for the BBPWA plant.

BBPWA doubled the plant capacity from 5 to 10 mgd during 2007 and 2008. Beginning in May 2008, BBPWA had sufficient treatment capacity to remove the 35% required level of TOC (Woods 2008). However, BBPWA is still in violation of the Stage 1 DBPR (ODEQ 2008a). As noted in the treatment plant schematic, chlorine is added in three locations. The piping from the treatment plant can bypass the 2 million gallon clearwell under certain operational conditions. Therefore, CT (required concentration of chlorine, C, in contact with the water over time, T) must be achieved using free chlorine in the WTP itself (Woods 2008). Adding free chlorine before the rapid mix and before the filters generates high concentrations of DBPs.

Lime is added to the rapid mix and just before the filters to boost the pH to levels in the range of 7.5 to 7.8 leaving the plant. The very low alkalinity in the raw water means that addition of alum doses at about 25 mg/L can drive the pH below 6 unless lime is used.

Table 9. Broken Bow PWA Water Treatment Processes

Treatment Parameter	Result
Type of Treatment	CONV
Approximate Plant Capacity, mgd	10
Coagulant Used	Alum, Polymer
Typical Coagulant Dose, mg/L	20-30, 0.5-0.9
Disinfectant Used	Chlorine
Typical Disinfectant Dose, mg/L	3.5-4.5
Typical Disinfectant Residual Leaving Plant, mg/L	2-2.5
Typical Disinfectant Residuals in Distribution System, mg/L	0.7-1.0
Other Treatment Chemicals Used	Lime
Typical Dose, mg/L	1-1.5
TOC Average Percent Removal 2005-2008	31%
Average TTHM 2005-2008, ppb	72
Average HAA5 2005-2008, ppb	77

Broken Bow PWA DBP Data

Graphs in Appendix E show Broken Bow PWA RAAs for TTHM and HAA5 since the fourth quarter of 2004. Over the entire period of record, the average TTHM and HAA5 values for Broken Bow PWA were 72 ppb and 77 ppb, respectively. The DBP levels in the Broken Bow PWA system are far higher than DBPs in the IRW systems. The plots in Appendix E indicate four TTHM MCL violations out of the last 17 quarters and 12 HAA5 MCL violations during the same period. On the ODEQ SDWIS website, 6 TTHM and 19 HAA5 MCL violations have been recorded since 2002. This violation level for BBPWA is far higher than the violations in any of the individual IRW systems. In fact, the total number of quarters of violations for the one Broken Bow Reservoir utility is over 70 percent of the IRW DBP violations **for all of the IRW utilities combined together**.

There is no guarantee that redoing the piping so that the 2 million gallon clearwell cannot be bypassed will result in compliance with the Stage 1 DBPR. The TOC levels in Broken Bow Reservoir are relatively high and the utility will have to practice TOC removal efficiencies even greater than the required 35% to comply with the current or upcoming DBP regulations.

Cooke and Welch Expert Report--DBPs

MCL Compliance

On page 12, Cooke and Welch (2008a) state: "DBP precursors in reservoirs are directly linked to the eutrophication process through total and dissolved organic carbon (TOC and DOC) drainage from the watershed and TOC-DOC production by algae in the river and reservoir." The authors do not provide a citation or data that support their claim in this section of the report. As discussed in the previous section of my report, linkage of DBP precursors to organic inputs into the IRW system is not knowable by Cooke and Welch nor can it be proven by anyone given the limitations of existing analytical methods.

On page 12, the authors discuss "threshold concentration values" established by the USEPA for DBPs. There is no such term as "threshold concentration values" or "threshold concentrations" in any of the thousands of pages of USEPA DBP regulations and supporting documentation. As stated previously in this report, the only regulatory limits for TTHM and HAA5 that water utilities are required to comply with are MCLs.

In the same paragraph on page 12, the authors introduce a term of their creation—"near-violations." No regulatory document created by the USEPA has ever used this term. To my knowledge, there is no peer-reviewed publication ever written that has used this term. The authors state that TTHM concentrations in the range of 72 to 79 ppb "may pose human health risks." They cited neither peer-reviewed publications nor any health-effects data which support this claim.

In Cooke's deposition (Cooke 2008a), he admitted that the terms created in his expert report are not related to compliance with the Stage 1 DBPR. He acknowledged that MCLs must be exceeded on the basis of RAAs in order for non-compliance with the Stage 1 DBPR to exist.

> " Q Do you agree that under Stage 1 that individual readings of 80 micrograms per liter do not constitute a violation of the EPA standards?
> A I do agree to that." (Cooke 2008a, page 200)

> "Q Is that just exceedances or near exceedances? [labeled as violations and near violations in the Cooke and Welch report]
> A These are the exceedances. There's one, two, three, four, five, six, seven of the eighteen that have not had an exceedance.
> Q Are you using single samples or running averages?
> A These are single -- these are their quarterly values, so they're single sample from that quarter.
> Q So it's not an EPA violation, is it?
> MR. PAGE: Object to the form.
> A It's not an EPA violation. (Cooke 2008a, page 206)

Cooke and Welch used terms in their report that they knew had no meaning based on the DBP regulatory requirements. Because they are not ignorant of the basis of DBP regulations and the requirements for water utilities that must meet these regulations, there is no logical explanation why these terms were used by Cooke and Welch. None of the discussions by Cooke and Welch of "threshold concentration values," "violations" or "near-violations" in their report have any basis in fact and should be ignored.

Cooke's Recent Concerns about Reproductive Toxicity of DBPs

In his deposition, Cooke (2008a) stated, beginning on page 154:

> "Q Have you put all your opinions about DBPs in your written report?
> A I have. I have stronger opinions now than I had when I wrote the report.
> Q Why?
> A More information.
> Q What information?
> A Mainly information from the periodical literature, and let me see if I can explain that. When you look at the disinfection byproduct reports that come from ODEQ, what you see is that in various quarters these utilities are in excess, and sometimes 20 or 30 percent of them are way in excess, especially on THMs, and then in a subsequent quarter, their numbers are back down again, and so the running four-quarter average shows that they're not out of compliance because that's the basis for determining in or out of compliance is the average you have on a running four-quarter basis, but the more I thought about this and began to look at periodical literature in this regard, and we'll be providing you a list of some of those reports if they're not already in here, is that there is a very definite link between drinking water that has disinfection byproducts in it at a level near but below the EPA threshold, a definite link between drinking that water and spontaneous abortions, meaning that this is short-term exposure that would cause that since the gestation time is nine or fewer months for humans, meaning that these one-quarter exceedances might alone be enough to provide that kind of embryo toxic environment.
>
> There are not very many people at some of these drinking water plants. They have customers that are less than -- a number of customers less than a thousand, but some of them are quite high, and Tahlequah would be an example of that. So then it -- and I don't have that very statement that I just gave you regarding spontaneous abortions in here [Cooke and Welch 2008a]. This just took additional thinking and an additional look at the literature."

It is surprising to me that Dr. Cooke is just becoming aware of the debate over reproductive toxicity issues and DBPs. The Agreement in Principle was signed in 2000 by all of the FACA committee stakeholders and clearly indicated that these health effects were considered in devising the Stage 2 rule:

> "In considering risks associated with DBPs, the Committee reviewed available toxicological and epidemiological data from a number of studies on reproductive and developmental health effects (e.g., early term miscarriages), as well as cancer.

> Despite the evaluation of a large amount of data, the Committee recognized that uncertainty remains in a number of areas regarding the precise nature and magnitude of risk associated with DBPs and pathogens in drinking water. In light of this uncertainty, the Committee recommended a series of balanced steps to address the areas of greatest health concern, taking into careful consideration the costs and potential impacts on public water systems." (USEPA 2000)

I personally sat through every minute of the FACA committee meetings in 1999-2000 and I can assure anyone that reproductive toxicity issues were considered in excruciating detail. The FACA committee members did not find that the reproductive toxicity issues were significant enough to dominate the requirements of the Stage 2 DBPR. For minutes of the FACA meetings, the USEPA website may be consulted (e.g., USEPA 1999)

An earlier section of my report that reviewed the basic requirements of the Stage 2 DBPR made it clear that three aspects of the regulation (i.e., IDSE, LRAA and Operational Evaluation Levels) were designed to curtail high, short term levels of DBPs in distribution systems to address the concerns expressed by the FACA negotiators about potential reproductive toxicity effects.

Dr. Cooke's opinions do not accurately reflect the basis of the Stage 2 DBPR or DBP reproductive toxicity issues that were addressed by the FACA committee over nine years ago.

Importance of Watershed Control of Precursors and AWWARF Research Role

On page 13, Cooke and Welch (2008a) stated:

> "...the American Water Works Association Research Foundation, as well as many other scientists (e.g. Stepczuk et al. 1998 a, b), advised utilities to attempt to lower DBP precursors in raw water by reducing precursor production in the watershed (e.g. wetland and agricultural runoff) and by reducing algae production in eutrophic reservoirs (e.g. Cooke and Carlson, 1989; Graham et al. 1998)."

Stepczuk et al. (1998a) did not advise utilities to reduce DBP precursors in their watersheds. At no point in this paper is such an advisory stated. Dr. Stepczuk's paper is a detailed discussion of DOC and THMFP monitoring during wet and dry seasons in the Delaware watershed of the New York City water supply.

Stepczuk et al. (1998b) did not advise utilities to reduce DBP precursors in their watersheds. This paper found that for Cannonsville Reservoir (in southern New York State) production of THM precursors in the reservoir was the dominant source even though no relationship between DOC and THM precursor levels could be determined.

While it is not even referenced in the Cooke and Welch (2008a) expert report, the third paper in the series by Stepczuk et al. (1998c) contained the most interesting discussion of reservoir management options based on their research findings. On page 377 of their paper, Stepczuk et al. (1998c) state:

> "This analysis represents strong support for nutrient loading **to be *considered*** in the management control of THM precursors in this reservoir (see also Cooke and Carlson 1989, Walker 1983). Managers are faced with the need to continue to meet standards for THMs that are becoming more restrictive, despite increasing costs of treatment. **It is therefore important that source (e.g., watershed) management be *evaluated* as a means to supplement or prevent the need for other options.** However reduction of nutrient and NOM loads from watersheds is **costly** and requires careful consideration." (emphasis added)

Stepczuk et al. (1989a, 1989b, 1998c) do not advise utilities to reduce DBP precursors in their watersheds. The authors suggest that this option be "considered" and "evaluated" along with other options such as treatment in WTPs. Also, Stepczuk et al. (1998c) realized that watershed control is costly. Cooke and Welch oversimplified the analysis of complex findings by other researchers. It is interesting to note that the Cooke and Welch oversimplifications support their main thesis.

Cooke and Welch committed a significant error by stating that AWWARF advised water utilities to do anything with regard to DBP precursors in their raw water supplies. AWWARF is a research organization that provides research grants to individuals and organizations to perform studies for the benefit of the water supply industry. Its research reports provide information to water utilities. I was a member of the Board of Trustees of AWWARF from 1983 to 1986 and I have conducted several million dollars of research funded by that organization. AWWARF never advises nor recommends that a water utility take any specific action. Cooke and Welch cite an AWWARF report (Cooke and Carlson 1989) where the issue of DBP precursor sources was investigated. On the Disclaimer page of that report was stated:

> "This study was funded by the American Water Works Association Research Foundation (AWWARF). AWWARF assumes no responsibility for the content of the research study reported in this publication, or for the opinions or statements of fact expressed in the report." (Cooke and Carlson 1989).

AWWARF does not advise or recommend that water utilities do anything with regard to water treatment or water quality control.

CDM DBP Survey

CDM sampled distribution system locations for DBP analysis for three water utilities in the IRW during the summer of 2006. There is no explanation in any plaintiffs' report that I am aware of why this sampling was conducted. The ODEQ SDWIS website is the official, comprehensive source for DBP compliance data for IRW utilities. Samples collected by a consulting engineering firm according to their private protocol and not based on the requirements of the Stage 1 DBPR cannot be analyzed for "violations" of the MCLs for TTHM and HAA5.

There is a significant question about the locations sampled from these three systems. It is stated in the report, "The CDM samples were taken…at locations that correspond to locations regularly sampled by plant personnel." It cannot be true that all of the locations sampled for two of the three utilities are "regularly sampled" for TTHM and HAA5 compliance. Gore PWA and Cherokee County RWD #2 serve less than 10,000 people. Therefore, they are only required to collect **one sample** from their distribution system each quarter at the maximum detention time. Therefore, four of the five samples collected by CDM at these two utilities cannot and do not correspond to the DBPMX sampling point and four of the five locations for two of the utilities are not regularly sampled by plant personnel for DBP compliance.

The CDM samples were collected and sent to Alpha Woods Hole Laboratory in Massachusetts. This laboratory is not certified by ODEQ to analyze drinking water samples for TTHM and HAA5 concentrations and provide compliance data for Oklahoma water utilities.

Comparing the TTHM and HAA5 compliance data on the SDWIS website (ODEQ 2008a) with the data presented by Cooke and Welch (2008a) on their Table 2, it appears that there were two examples where the CDM data were significantly different from the official levels of TTHM and HAA5 in the three distribution systems. One location in the Cherokee County RWD #2 system (John Bates) and one location in Tahlequah PWA (WPC Plant) resulted in TTHM and HAA5 levels that were far above typical TTHM and HAA5 compliance values for these utilities.

Based on the facts that only one quarter of one year was sampled (summer of 2006), that sample locations were used that were not part of the DBP compliance monitoring points for two of the utilities and that a laboratory was used to analyze the data that was not certified by the State of Oklahoma for DBP analysis, all of the data collected by CDM and discussed by Cooke and Welch are irrelevant to DBP regulatory compliance. Cooke and Welch conclusions and opinions based on the CDM-collected TTHM and HAA5 data have neither scientific nor regulatory relevance.

Cooke and Welch Report DBP Data Analysis

Appendix A of the Cooke and Welch (2008a) report contained the TTHM and HAA5 data from the IRW utilities on which they based their opinions. Stated in the heading of the Appendix A table is the statement "(obtained from the SDWIS on ODEQ website)." Using this data, Cooke and Welch calculated the percent "violations" or "near violations" as they (improperly) defined them.

Table 10 shows a selection of 36 values from Appendix A from the Cook and Welch (2008a) report that are in perfect agreement with data from the Environmental Working Group (EWG) National Tap Water Database (EWG 2008). Cooke and Welch (2008a) have imported TTHM values from the EWG National Tap Water Database into their supposed ODEQ SDWIS data set. The Environmental Working Group is a non-governmental, non-profit organization supported by individual donations and private foundations. It is a tremendous understatement to note that samples collected by EWG should not be combined with or identified as ODEQ SDWIS TTHM data.

There is no assurance that the EWG data were collected properly and that the correct analytical method was used or that proper quality control procedures were maintained. Water quality data collected by volunteers from an environmental group have no place in a table labeled, "obtained from the SDWIS on ODEQ website." Also, none of the EWG data should be considered as regulatory compliance data. At best, the EWG data are estimates of DBP values in IRW water utility distribution systems.

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Overall, 66 TTHM values from the EWG database were included in Appendix A or 13 percent of the 500 data points in Appendix A. This is an egregious error by Cooke and Welch and one more reason why their conclusions and opinions based on their TTHM and HAA5 data should be ignored.

Table 10. Comparison of a Subset of IRW Utility TTHM Data—EWG vs. Cooke and Welch (EWG 2008, Cooke and Welch 2008a)

Utility	Sample Date	EWG Result, ppb	Cooke & Welch Appendix A, ppb
Cherokee Co #2	8/27/2002	67	67
	5/13/2002	60.1	60.1
	2/26/2002	29.9	29.9
	12/17/2001	38	38
	9/19/2001	88.6	88.6
	8/27/2001	81.1	81.1
	4/10/2001	55.6	55.6
	1/22/2001	26.5	26.5
	10/3/2000	59.8	59.8
	7/30/2000	153.9	153.9
	6/5/2000	147.14	147.14
	5/2/2000	55.21	55.21
East Central OK	1/21/2003	46.3	46.3
	1/14/2002	37.65	37.65
	12/18/2001	63.6	63.6
	10/16/2001	94.8	94.8
	4/30/2001	48.9	48.9
	2/6/2001	61.3	61.3
	11/14/2000	48.4	48.4
	5/1/2000	41.86	41.86
Pettit MT	10/29/2002	126.4	126.4
Sequoyah Co WA	2/4/2003	63	63
	2/4/2003	51	51
	11/5/2002	77	73
	11/5/2002	53	53
	8/6/2002	139	139
	8/6/2002	140	140
	5/7/2002	91	91
	5/7/2002	114	114
	2/13/2002	62	62
	2/13/2002	16	16
	11/6/2001	53	53
	11/6/2001	58	58
	8/29/2001	44	44
	8/29/2001	62	62
Tenkiller Utility Co	9/25/2002	85.8	85.8

Incredibly, Dr. Cooke (Cooke 2008a) in his deposition on pages 163-164 and 166-167, stated that he did not trust the data from the EWG database:

> "Q Do you believe the National Tap Water Quality Database to be a credible database?
> A I had no reason to until I saw their Tahlequah numbers, and they show sample after sample after sample in Tahlequah with zeros for trihalomethanes and HAA5s, and such is not the case if we can believe ODEQ, and ODEQ has the numbers directly from the utilities. So the National Tap Water Database somehow or another was -- maybe they just didn't input the numbers correctly when somebody typed it in, but they were wrong and my suspicion level went up significantly at that point."
>
> and
>
> "Q Is that the first time that you had ever used the National Tap Water Quality Database?
> A Yes.
> Q Have you used it since then?
> A No, and I'm not going to use it again either."

Either Dr. Cooke did not know that EWG data was included in Appendix A upon which he has relied for his opinion, or he has changed his opinion of the validity of the EWG database between the time he wrote his report and the time he gave his deposition.

There is a very curious error on page 14 of the Cooke and Welch (2008a) report. They state "Fin and Feather Resort (Tenkiller), Adair Co. RWD #5, and Flint Ridge (Illinois River) did not report DBPs in their tap water over an 8 year span (Table 1)." Their own Appendix A shows DBP data from these three utilities from 1999 to present. Stage 1 DBPR compliance data from 2002 (or 2004) to present is included in their Appendix A for these three utilities. Cooke and Welch were obviously relying on their Table 1 to make this quoted statement when their own data tables showed that they made an error. Any of their opinions based on their data analyses must be questioned if they cannot interpret their own data correctly.

None of the "violations" and "near violations" discussed on page 14 of Cooke and Welch (2008a) based on the ODEQ data from the SDWIS site have any relevance to the definition of violations of the TTHM and HAA5 MCLs. As previously discussed in this report, the term "near violation" created by Cooke and Welch does not exist in any regulatory documents or peer-reviewed literature.

Compliance with the TTHM and HAA5 MCLs must be based on a running annual average of quarterly average data. None of the requirements of the Stage 1 DBPR are included in analysis of the SDWIS DBP data by Cooke and Welch (2008a). They label as a "violation" any time a value for one sample collected at any place in the distribution system exceeded the numerical values of 80 ppb for TTHM and 60 ppb for HAA5. Their determinations of violations are clearly wrong. Their presentation of the TTHM data from Tahlequah on their Figure 4 is similarly wrong. Their label of 80 ppb as the "violation line" is incorrect. In fact, Tahlequah PWA has never been cited by Oklahoma or the USEPA for a violation of the TTHM or HAA5 MCLs even though Cooke and Welch claim that Tahlequah has violated those limits.

Therefore, the statements in the Cooke and Welch (2008a) report regarding violations of the TTHM and HAA5 MCLs are not correct. All of the conclusions and opinions made by Cooke and Welch based on their evaluation of "violations" as defined by them should not be considered.

Trihalomethane Formation Potential and Sources of TOC

On page 15 of their report, Cooke and Welch (2008a) refer to "...THM precursor molecules such as those that are produced by algae or transported to the reservoir from land runoff or from the synthesis by river algae." The authors have obviously left out a number of important sources of THM precursors—(1) naturally occurring organic matter from the extraction by water of humic and fulvic acids from leaves, bark, wood and natural organics in soils, and (2) organics discharged by wastewater treatment plants and other sources identified in my Figure 3. At no point in their report, do the authors admit that THM precursors may be coming from any source other than the sources they believe are related to poultry litter. Cooke and Welch have only presented data and references which support their point of view.

Their statement on page 15 "The appearance of DBPs in tap water is causally linked to eutrophication of the water supply" is clearly incomplete and incorrect. The online Merriam-Webster Dictionary defines "causal" as "expressing or indicating cause." The statement by Cooke and Welch leaves the reader with the clear impression that eutrophication is the ONLY source or cause of DBPs appearing in tap water. This impression and their statement are wrong. DBPs are present in tap water because of a myriad of reasons. Chlorine dose, contact time, pH and temperature are just a few of the factors not considered by Cooke and Welch that influence DBP production besides organic precursors. DBP precursors come from a variety of sources other than those claimed by the authors—see my Figure 3. Cooke and Welch quote the results of a number of studies that link algae growth in water bodies to the production of DBP precursors. While the conclusions of the authors of the other studies may have been correct for the water bodies that they studied, Cooke and Welch present no data that definitively show that algae growth in the IRW is directly connected to DBPs in the tap water of IRW water utilities.

Cooke and Welch (2008a) quote Olsen (2008) as a source for TOC levels increasing from the Illinois River to Lake Tenkiller (page 15): "TOC in the reservoir averaged 2.5 mg/L, vs. 1.5 mg/L in the inflowing water (Olsen, 2008)." They then state with no proof whatsoever that "The additional TOC in the reservoir was produced by its algae." Olsen (2008) presented TOC data for a number of sampling locations in the Illinois River and Lake Tenkiller. Table 6.5-1 and Figure 6.5-9 of Olsen's expert report do not support the average TOC data quoted by Cooke and Welch. Table 6.5-1 lists average TOC values for Illinois River sampling locations that ranged from 1.66

to 4.65 mg/L which are higher than the TOC average Cooke and Welch quoted of 1.5 mg/L. Median TOC values shown on Figure 6.5-9 for the Illinois River ranged from about 1.7 to 2.9 mg/L, which are also above the "average" that is quoted by Cooke and Welch.

The Cooke and Welch (2008a) TOC data do not match up with TOC data in Olsen's (2008) report for Lake Tenkiller. From Table 6.5-1, the average TOC value for Lake Tenkiller sampling locations was listed as 2.15 mg/L which is different from the average TOC value of 2.5 mg/L claimed by Cooke and Welch. Based on the actual data from Olsen (2008), the plaintiff's experts have not demonstrated any increase in TOC values from the Illinois River to Lake Tenkiller.

Therefore, the entire argument by Cooke and Welch that algae-produced DBPs in tap water are "causally linked to eutrophication of the water supply" is disputed by the plaintiffs' own data.

In their expert report on page 13, Cooke and Welch (2008a) stated that utilities should lower DBP precursors in raw water by reducing precursor production in the watershed (e.g. wetland and agricultural runoff) and by reducing algae production in eutrophic reservoirs. As support for that recommendation, Cooke and Welch (2008a) cited the AWWARF report by Cooke and Carlson (1989).

In the 1989 AWWARF publication (page 313), the following statement was made in the Summary and Conclusions section:

> "One of the major conclusions of this project, however, is that ***little is known* of the condition of water supply reservoirs and lakes, and their responses to management techniques**. There are few data regarding improvements in finished drinking water, especially with regard to THM concentrations, following implementation of a particular technique. It is ***only hypothesized*** that because algae, weeds, and sediments appear to be major THM precursor sources that their long-term control through appropriate water supply protection, management, and restoration will bring about significant reductions in THM concentrations in finished drinking water." (emphasis added)

Therefore, Cooke and Welch cited a report that was co-authored by Dr. Cooke which said exactly the opposite of what was claimed in their expert report. Cooke and Carlson admitted in 1989 that they could not demonstrate that controlling algae would reduce THM concentrations in treated drinking water which is a major conclusion of the Cooke and Welch (2008a) expert report.

A recent publication on precisely this topic showed that little or no progress has been made demonstrating a definitive connection between controlling algae and reducing THMs. A paper by Bukaveckas et al. (2007) evaluated the complex inputs of DBP precursors into Taylorsville Lake, Kentucky. One of the findings was a failure to correlate THMFP with *chlorophyll-a* in either the lake or its inflows. Bukaveckas et al. (2007) confirmed that there was no "causal" connection that has been proven between inputs of nutrients, algae blooms and DBP production and that no clear strategies to manage these inputs have been determined.

> "Watersheds experiencing agriculture, logging, or other activities that promote erosion ***may*** receive elevated loadings of DBP precursors because of inputs of dissolved organic carbon (DOC) and particulate organic carbon. Source water proximal to urban and agricultural areas also receive elevated inputs of inorganic nutrients and experience excessive phytoplankton blooms that ***may*** promote generation of precursors. ***Scientific understanding of the links between watershed development and DBPs is poor*** in part because few studies have considered precursor issues in the context of the ecosystem processes. Pending regulations increase the urgency to address the ultimate questions of why water sources vary widely in DBPFP [disinfection byproducts formation potential] and how source waters and their catchments can be managed to reduce DBPs." (emphasis added) (Bukaveckas et al. 2007)

Application of Canadian DBP Model to Lake Tenkiller Utilities

On page 16, Cooke and Welch (2008a) introduced a "five variable model" that purported to predict the probability of exceeding DBP "violation thresholds" in tap water. The model was based on the weather, water utility characteristics, sources and DOC concentrations of Canadian utilities located in the province of Quebec, Canada. The model is based on a regression analysis using information from the Canadian utilities. Sources of supply for the Canadian utilities include lakes, reservoirs and rivers in a Canadian province that extends almost to the Arctic Circle.

Cooke and Welch used this model without any evidence that it represented the conditions in the IRW to supposedly predict that there was a 40% to 65% chance of exceeding the 80 ppb "USEPA threshold" based on the TOC data from the CDM monitoring during the summer of 2006. It was inappropriate for Cooke and Welch to use a model that had not been verified as applicable to the IRW (e.g., temperature ranges, sources of precursors, nature of natural organic matter) to predict anything having to do with water served by utilities using Lake Tenkiller or the Illinois River. Any conclusions based on the improper use of the Canadian model to predict any DBP occurrence in the IRW should not be considered.

Comparison of Water Quality in Lake Tenkiller and Broken Bow Reservoir

In their report, Cooke and Welch (2008a) go to great pains to compare the trophic status of Lake Tenkiller and Broken Bow Reservoir. They claim that Broken Bow Reservoir is "unproductive" and that "The disposal of poultry waste on the extensive pastures in the Tenkiller watershed contributes to the large differences in water quality between these two reservoirs (Engel, 2008)."

The expert opinions in my report do not deal with the foundation for determining trophic status of any reservoir, principal component analysis or the specific sources of phosphorus in the watersheds. However, Cooke and Welch attempt to connect what they claim to be the higher productivity of Lake Tenkiller to public health problems associated with DBPs. On page 16 in the Cooke and Welch (2008a) report, they state,

> "The high algal productivity of Tenkiller, and the associated production of THM precursors by the algae, was caused by the high P concentration in Tenkiller water which